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NUMBER 103

AUTOMATIC SCREW MACHINE PRACTICE

PART V

INTERNAL CUTTING TOOLS FOR BROWN & SHARPE AUTOMATIC SCREW MACHINES

By DOUGLAS T. HAMILTON

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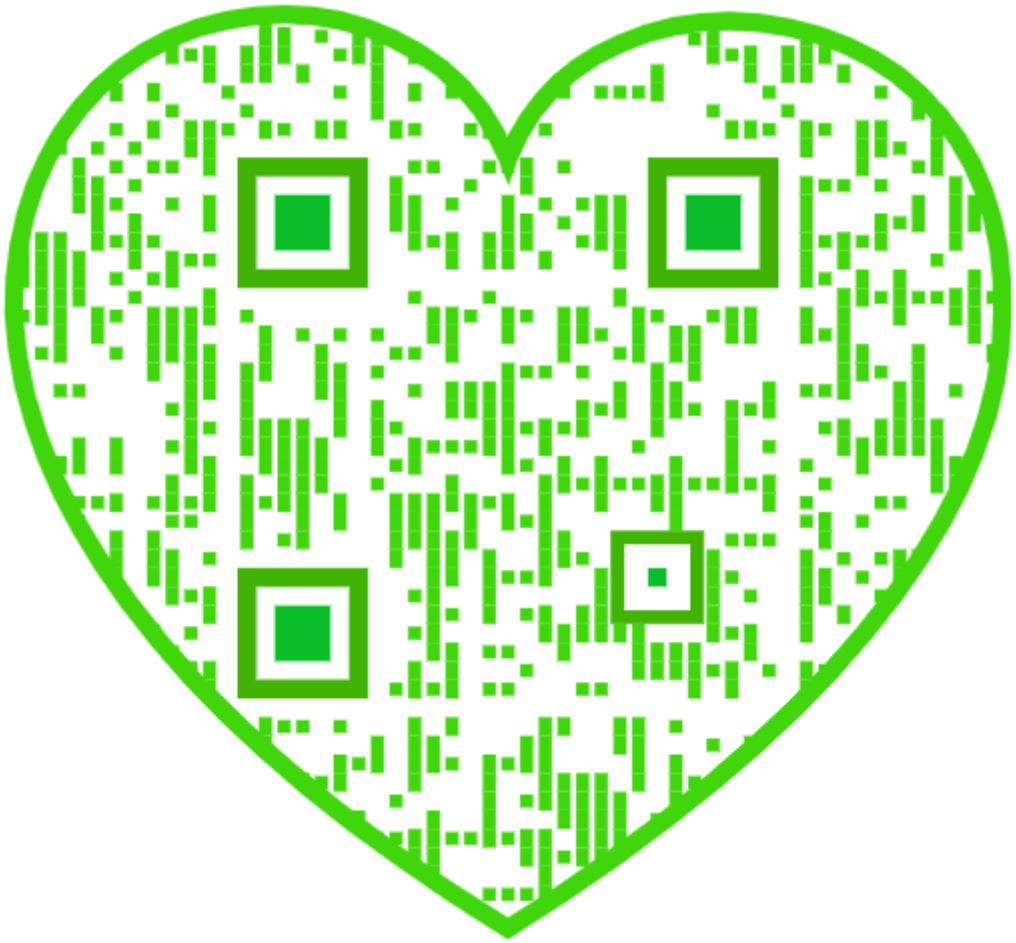

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Automatic Screw Machine Practice for the Brown & Sharpe automatic screw machines is covered in eight Reference Books, Nos. 99 to 106, inclusive. Reference Book No. 99, "Operation of the Brown & Sharpe Automatic Screw Machines," deals with the construction of these machines and the setting-up of the tools. No. 100, "Designing and Cutting Cams for Automatic Screw Machines," gives detailed instruction on cam design, and describes a simplified method for milling cams. No. 101, "Circular Form and Cut-off Tools for the Automatic Screw Machine," deals with the general arrangement and the calculations of these tools, and describes the different methods employed in their making. No. 102, "External Cutting Tools for the Automatic Screw Machine," deals with the design and construction of box-tools, taper turning tools, hollow mills, and shaving tools. No. 103, "Internal Cutting Tools for the Automatic Screw Machine," deals with centering tools, cross-slide drilling attachments, counterbores, reamers, and recessing tools. No. 104, "Threading Operations on the Automatic Screw Machine," treats on cam design for threading operations, threading dies, taps and tap drills, die and tap holders, and thread rolling. No. 105, "Knurling Operations on the Automatic Screw Machine," describes the construction of knurling holders, and gives directions for the making of knurls and the design of tools and cams used in connection with knurling operations. No. 106, "Milling, Cross-drilling and Burring Operations on the Automatic Screw Machine," describes screw-slotting attachments, index drilling attachments, and burring attachments, giving directions for their use and for the design of cams for them.

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CHAPTER I

CENTERING AND DRILLING OPERATIONS

The conditions met with on the Brown & Sharpe automatic screw machines are such that, for general work, the simpler the design of the tool used, the more efficient the results obtained. Of course, in some cases it is necessary, where difficult shapes are to be formed, to make the tools somewhat complicated, but even then the simplest design possible should be adopted. It is obvious that in internal cutting there is more chance of the tool sticking and breaking, due to the clogging of chips and improper lubrication, than on external work. It is therefore necessary to make all cutting tools for internal work with as much chip space as possble, and also to provide means for proper lubrication. The periphery clearance given to the tools also has an important bearing on their efficiency. Where there is too much cutting surface in contact with the work, the tendency is to produce rough work and also to break the tool, as heating is developed at the point of contact, thus causing the tool and work to seize.

In making complicated tools for internal work the excessive use of springs, especially when flat, is objectionable, for if the spring fails to work, the cutting tool is generally broken. If a spring is necessary, a coil spring should be used, and provision should be made to have it long enough so that it will retain, as much as possible, its initial tension. Springs for internal cutting tools, as well as for other tools of a similar character, should always be tempered in oil, as this increases their life. The design of an internal cutting tool is largely governed by the material which it is to cut and the amount of material it is required to remove.

Centering and Centering Tools

When drilling holes which are less than 3/16 inch in diameter it is always advisable, especially when the hole passes through the work, to use a starting or centering tool. At *A* in Fig. 1 is shown a centering tool which is used for brass work, and at *B* one which is used for steel and soft iron. This latter tool is similar to the ordinary twist drill, except that the flutes are shorter. A worn-out twist drill is sometimes used for this purpose, with the point ground thin, as shown at *a*, which reduces the pressure and allows the drill to start easier. This tool also makes a better center than would a drill with a thicker point. The included angle of the cutting edges on a centering tool should be less than the drill which is to follow. If this is not the case, the point of the drill will start to cut before the body of the drill is properly supported; consequently, an imperfect center will be formed. If an imperfect center has been formed, the drill will run out, as is clearly shown at *C* in Fig. 1. It can be seen that it is practically impossible

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for a drill to start concentric with the center of the work when a small teat, as shown, has been left by the centering tool. Using a centering tool with a more acute angle obviates this trouble, as the body of the drill is well supported before the point of the drill starts to cut. This is clearly shown at *D* in Fig. 1. The included angle of the point which has been found most suitable for centering tools varies from 90 to 100 degrees; 90 degrees should be used, preferably, for brass, and 100 degrees for steel. The included angle of the point of the drill varies from 118 to 120 degrees, 118 degrees being generally used for the drill, as it has been found to give the best results. In Table I is given the length of the point for centering tools and twist drills, having included angles of 90 and 118 degrees, respectively. The

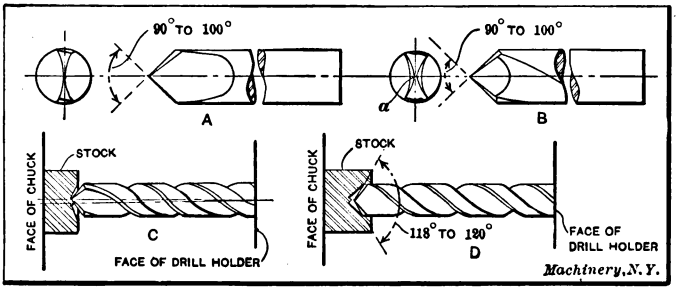

Fig. 1. Centering Tools—Starting the Drill Concentric

formulas for finding the length of point for the various angles are as follows (see Fig. 2):

For 90 degrees $b = 0.5d$.
For 100 degrees $b = 0.42d$.
For 118 degrees $e = 0.3c$.
For 120 degrees $e = 0.29c$.

where b = depth of centered hole,
c = diameter of drill,
d = diameter of centered hole,
e = length of drill point.

Cam Rise for Centering

When the length of the point of the centering tool is known, it is an easy matter to find the rise on the cam required for centering. There are four different conditions governing the amount of rise required for centering, which are as follows:

First: When the drill does not pass through the work and a stop for gaging the stock to length is used.

Second: When the drill passes through the work and a stop for gaging the stock to length is used.

Third: When the drill does not pass through the work and a stop for gaging the stock to length is not used.

Fourth: When the drill passes through the work and a stop for gaging the stock to length is not used.

The rises on the cam for centering as governed by the previous conditions are as follows (see Fig. 2):

First: $R = b + 0.010$ inch;

TABLE I. LENGTH OF POINT ON TWIST DRILLS AND CENTERING TOOLS

Size of Drill or Diameter of Center	Decimal Equivalent	Length of Point when Included Angle = 90°	Length of Point when Included Angle = 118°	Size of Drill or Diameter of Center	Decimal Equivalent	Length of Point when Included Angle = 90°	Length of Point when Included Angle = 118°	Size of Drill or Diameter of Center	Decimal Equivalent	Length of Point when Included Angle = 90°	Length of Point when Included Angle = 118°	Size of Drill or Diameter of Center	Decimal Equivalent	Length of Point when Included Angle = 90°	Length of Point when Included Angle = 118°
60	0.0400	0.020	0.012	41	0.0960	0.048	0.029	22	0.1570	0.079	0.047	3	0.2130	0.107	0.064	31/64	0.4844	0.242	0.145
59	0.0410	0.021	0.012	40	0.0980	0.049	0.029	21	0.1590	0.080	0.048	2	0.2210	0.111	0.067	1/2	0.5000	0.250	0.150
58	0.0420	0.021	0.013	39	0.0995	0.050	0.030	20	0.1610	0.081	0.048	1	0.2280	0.114	0.068	33/64	0.5156	0.258	0.155
57	0.0430	0.022	0.013	38	0.1015	0.051	0.030	19	0.1660	0.083	0.050	1/4	0.2344	0.117	0.070	17/32	0.5313	0.266	0.159
56	0.0465	0.023	0.014	37	0.1040	0.052	0.031	18	0.1695	0.085	0.051	1/4	0.2500	0.125	0.075	35/64	0.5469	0.273	0.164
55	0.0520	0.026	0.016	36	0.1065	0.054	0.032	17	0.1730	0.087	0.052	9/64	0.2656	0.133	0.080	9/16	0.5625	0.281	0.169
54	0.0550	0.028	0.017	35	0.1100	0.055	0.033	16	0.1770	0.089	0.053	9/64	0.2813	0.141	0.084	37/64	0.5781	0.289	0.173
53	0.0595	0.030	0.018	34	0.1110	0.056	0.033	15	0.1800	0.090	0.054	19/64	0.2969	0.148	0.089	19/32	0.5938	0.297	0.178
52	0.0635	0.032	0.019	33	0.1130	0.057	0.034	14	0.1820	0.091	0.055	5/16	0.3125	0.156	0.094	39/64	0.6094	0.305	0.183
51	0.0670	0.034	0.020	32	0.1160	0.058	0.035	13	0.1850	0.093	0.056	21/64	0.3281	0.164	0.098	5/8	0.6250	0.313	0.188
50	0.0700	0.035	0.021	31	0.1200	0.060	0.036	12	0.1890	0.095	0.057	11/32	0.3438	0.171	0.103	41/64	0.6406	0.320	0.192
49	0.0730	0.037	0.022	30	0.1285	0.065	0.039	11	0.1910	0.096	0.057	23/64	0.3594	0.180	0.108	21/32	0.6563	0.328	0.197
48	0.0760	0.038	0.023	29	0.1360	0.068	0.041	10	0.1935	0.097	0.058	3/8	0.3750	0.188	0.113	43/64	0.6719	0.336	0.202
47	0.0785	0.040	0.024	28	0.1405	0.070	0.042	9	0.1960	0.098	0.059	25/64	0.3906	0.195	0.117	11/16	0.6875	0.344	0.206
46	0.0810	0.041	0.024	27	0.1440	0.072	0.043	8	0.1990	0.100	0.060	13/32	0.4063	0.203	0.122	45/64	0.7188	0.359	0.216
45	0.0820	0.041	0.025	26	0.1470	0.074	0.044	7	0.2010	0.101	0.060	27/64	0.4219	0.211	0.127	3/4	0.7500	0.375	0.225
44	0.0860	0.043	0.026	25	0.1495	0.075	0.045	6	0.2040	0.102	0.061	7/16	0.4375	0.219	0.131	49/64	0.7813	0.391	0.234
43	0.0890	0.045	0.027	24	0.1520	0.076	0.046	5	0.2055	0.103	0.062	29/64	0.4531	0.227	0.136	13/16	0.8125	0.406	0.244
42	0.0935	0.047	0.028	23	0.1540	0.077	0.046	4	0.2090	0.105	0.063	15/32	0.4688	0.234	0.141	53/64	0.8438	0.422	0.253

Second: $R = b - e + 0.010$ inch;

where R = rise on cam for centering,
b = depth of centered hole,
e = length of point on drill.

It will be noted that when using the second method, the rise on the cam would not be sufficient, on starting a new rod, to allow the centering tool to travel the full distance; or, in other words, would not be equal to the length of the point of the centering tool used. The correct way to start a new bar, however, is to throw over the operating lever, thus stopping the operation of the machine; then open the chuck by hand and feed the stock out just past the cutting-off tool, so as to allow it to face off from 1/16 to 1/8 inch from the end of the

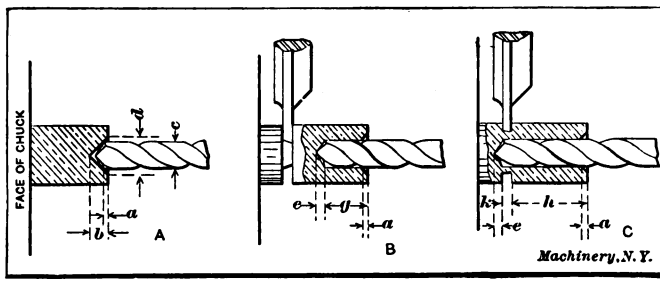

Fig. 2. Diagrams illustrating Method of Finding Cam Rise for Drilling and Centering

bar. Then the stock is fed out by hand, and the centering tool also operated by the hand lever, after which the machine can be started.

Third: The rise for the various machines is as follows:

For the No. 00, $R = b + 0.020$ inch.
For the No. 0, $R = b + 0.028$ inch.
For the No. 2, $R = b + 0.035$ inch.

The values which are added to b are for facing, and the feeds should be decreased for this. A dwell should also be allowed on the cam varying from 2 to 5 revolutions, the number of revolutions necessary being governed by the material to be cut. The dwell should be longer for steel than for brass stock. The feed for facing brass should be from 0.0015 to 0.002 inch per revolution, and for steel from 0.001 to 0.0012 inch per revolution.

Fourth: The rise for the various machines is as follows:

For the No. 00, $R = b - e + 0.020$ inch.
For the No. 0, $R = b - e + 0.028$ inch.
For the No. 2, $R = b - e + 0.035$ inch.

The feed should be decreased for facing, and a dwell of from 2 to 5 revolutions allowed. The suggestions previously given for starting a new bar should also be remembered. The time for starting a new bar in the manner given is practically negligible, as the machine anyway should always be stopped when a new bar is being inserted.

Special Centering Tool for Hard Material

The included angle of the point on the centering tools shown at *A* and *B* in Fig. 1 gives satisfactory results when used on soft material, such as brass or soft steel; but when the material is of a harder nature, trouble is sometimes encountered with the point of the centering tool breaking. This can be obviated by making a centering tool as shown in Fig. 3. This tool has a double angle, the extreme point being made to an included angle of 118 degrees, while the remaining

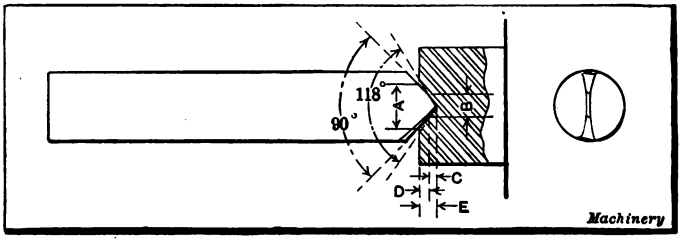

Fig. 3. Double-angle Centering Tool

part of the cutting edge is made to an included angle of 90 degrees. This strengthens the point of the tool, while at the same time it permits the drill to be supported by the center before the point starts to cut.

The following formulas are used for finding the dimensions (see Fig. 3):

$$B = \frac{A}{2};\quad C = B \times 0.3;\quad D = A \times 0.25;$$

$$E = A \times 0.4;\quad R = E + 0.010.$$

TABLE II. FEEDS FOR CENTERING TOOLS

Diameter in Inches	Feed in Inches per Revolution		
	Brass Rod	Machine Steel	Tool Steel
1/4	0.004	0.003	0.002
5/16	0.004	0.004	0.003
3/8	0.005	0.0045	0 004
1/2	0.0055	0.005	0.0045
3/4	0.006	0.005	0.005
1	0.0065	0 005	0 0055

in which A = diameter of center in the work,
B = diameter of point where the 118-degree angle terminates,
C = length of point with 118-degree included angle.
D = length of part with 90-degree included angle.
E = total depth of centered hole,
R = rise on cam for centering (first condition).

Speeds and Feeds for Centering

The surface speeds for centering tools should be the same as for drills, a table for which will be given later. The feed for centering

tools (as they are generally large enough to stand a heavy feed) is also the same in most cases. Table II gives the feeds for centering tools having diameters as specified. These feeds have been found satisfactory for general work.

Centering Tool Holders

The manner in which a centering tool is held when applied to the work governs to a considerable extent the results obtained. The tool should be held rigidly and concentric with the center of the work if

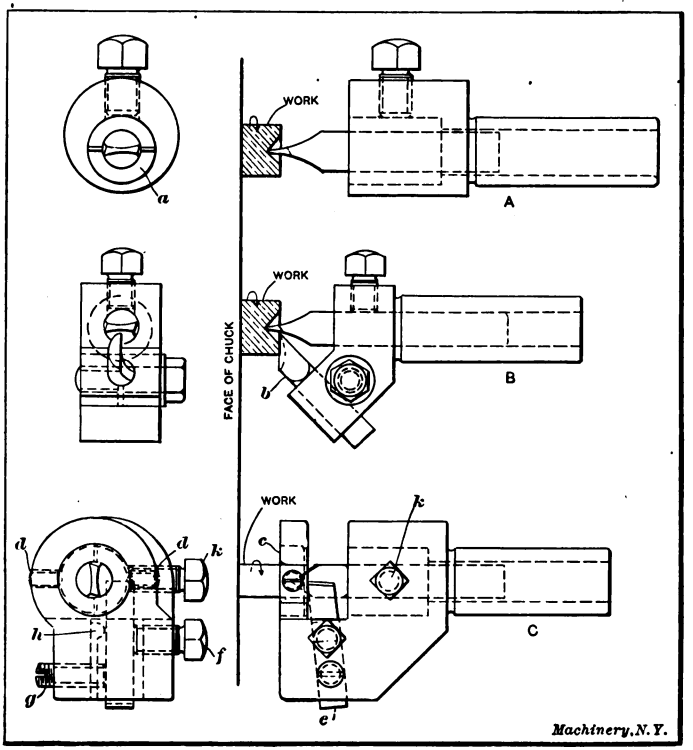

Fig. 4. Various Types of Centering Tool Holders

an imperfect center, as shown at *C* in Fig. 1, is to be avoided. At *A* in Fig. 4 is shown a common form of centering tool holder. This holder has been found very successful for general conditions when the work has been gaged to length by a stop, thus obviating the necessity of using a facing tool. It is provided with a split bushing *a*, as shown in the end view, or is made without the bushing, the hole for the centering tool simply passing through the body and the shank, and being of the same diameter as the centering tool. In most cases the holder with the split bushing is preferable, as the tool is more easily set concentric with the center of the work. At *B* in Fig. 4 is shown a combination centering and facing tool holder. This holder is used when

the stop for gaging the work to length has been dispensed with, the tool *b* being used for facing the work to the required length. This is found to be a very suitable holder when the work does not project more than 2½ times its diameter from the face of the chuck. At *C* in Fig. 4 is shown a combination centering and facing tool holder with a supporting bushing *c*, which is held in the body of the tool by two headless screws *d*, shown in the end view. The centering tool is held in a split bushing by set-screw *k*. The turning or facing tool *e* is adjusted to cut the required diameter by set-screw *f* and headless screws *g*, the block *h* acting as a fulcrum. This holder is used when the work has been turned before centering, and it is also found convenient for centering long and slender work. A Brown & Sharpe floating holder is used for holding the centering tool when the turret and spindle are not concentric, or when extreme accuracy is desired.

Drills and Drilling

For general work commercial drills of the two-fluted type are used exclusively on the Brown & Sharpe automatic screw machines for drilling cylindrical holes. The spiral fluted drill is used for drilling machine steel, Norway iron, etc., and also for shallow holes in brass; but when deep holes are to be drilled in brass, a straight-fluted drill should be used in preference to a spiral drill, as it breaks up the chips, allowing them to be removed with greater ease. The grinding of the lips on the cutting edge of the drill has a considerable bearing on the shape of the chips produced and also on the amount of power required to force the drill into the work. If the angle as previously given is used, and if the point of the twist drill is ground thin, it will produce a long, curling chip, and will not require much power for drilling. When drilling, if the edges of the drill burn, it is an indication that the surface speed is too high; if the drill chips, the feed is too great; and if the drill splits at the point, that the proper clearance has not been given at the cutting edges. If the centering tool and drill have been ground to the correct included point-angle there is no reason why the drill should not produce a straight and cylindrical hole, provided the feed is not too heavy.

Cam Rise for Drilling

There are three general conditions which govern the amount of rise required for drilling. They are as follows:

First: When the drill does not pass through the work and a centering tool is not used.

Second: When the drill does not pass through the work and a centering tool is used.

Third: When the drill passes through the work and a centering tool is used.

There is also another condition, *viz.*, when the drill passes through the work and a centering tool is not used; but as this is not a commendable method, it is not here considered.

The rise on the cam for drilling as governed by the previous conditions is as follows:

First: $R = g + e + 0.010$ inch (see B in Fig. 2).

Second: $R = g - a + 0.010$ inch (see B in Fig. 2).

Third: $R = h + k - a + 0.010$ inch (see C in Fig. 2).

where R = rise on cam for drilling,
g = depth of hole to be drilled,
e = length of point on the drill (see Table I),
h = overall length of the work,
k = thickness of the cut-off tool,
a = distance that the straight part of the drill projects from the face of the work into the centered hole before starting to cut (see A in Fig. 2).

The values of a for centering tools having 90- and 100-degree point-angles are as follows:

For 90 degrees, $a = (d - c) \times 0.5$ inch.
For 100 degrees, $a = (d - c) \times 0.43$ inch.

where d = diameter of centered hole,
c = diameter of drill.

Deep-hole Drilling

The automatic screw machine lends itself to the production of *straight* holes, but when producing *deep* holes there are a number of difficulties to overcome: In the first place, the drill is not at the will of the operator, and cannot be withdrawn from the work when it begins to seize or plug up with chips; in the second place, keeping the point of the drill cool and removing the chips is a difficult proposition; and, in the third place, the feed of the drill is governed automatically. It is, therefore, necessary to have the drill well lubricated and the feed moderate.

For shallow holes the best results are obtained by giving a rotary motion to the work and a feeding motion to the drill, but when drilling deep holes, the drill and the work should both be given a rotary motion. This helps to clear the chips from the hole and also allows oil to penetrate to the cutting point of the drill.

When drilling deep holes the drill should not penetrate into the work more than two and one-half times the diameter of the drill before being withdrawn from the work. For drilling deep holes in tool and machine steel, the spiral fluted drill is generally used with good results, but for drilling deep holes in brass, the straight-fluted drill gives better satisfaction, as it does not produce a long, curling chip, which is generally objectionable. Further information on the subject of deep hole drilling can be obtained from MACHINERY'S Reference Book No. 25, "Deep Hole Drilling."

Designing Cams for Deep-hole Drilling

As was previously mentioned, the drill should be dropped back clear of the drilled hole, so that the chips can be removed from the flutes

and the drill cooled and lubricated. To accomplish this the lead cam is laid out as shown in Fig. 5; to explain the method used for laying out the cam, we will take a practical example: Assume that a hole ⅛ inch in diameter and ⅞ inch long is to be drilled in a piece of brass rod. Now, it can be seen that this will require three distinct lobes on the cam, as it will be necessary to drop the drill back twice in producing the hole. The rises for the various lobes can be found with the aid of the following formulas:

Rise on first lobe $= 2\frac{3}{4} \times D + 0.005$ inch.
Rise on second lobe $= 2\frac{3}{8} \times D + 0.003$ inch.
Rise on third lobe $= 2 \times D + 0.003$ inch.
where D = diameter of drill in inches.

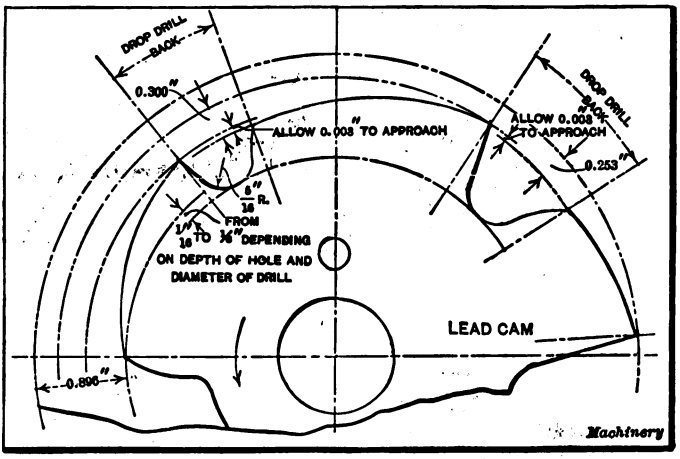

Fig. 5. Method of Laying out Cams for Deep-hole Drilling

The amount for each successive rise should be decreased in about the same proportion, and the feed on the drill should also be decreased slightly for each additional lobe when cutting machine and tool steel; but when cutting brass the feed can generally be uniform for each lobe. The rise on the various lobes would then be as follows:

Rise on first lobe $= 2\frac{3}{4} \times \frac{1}{8} + 0.005 = 0.349$ inch.
Rise on second lobe $= 2\frac{3}{8} \times \frac{1}{8} + 0.003 = 0.300$ inch.
Rise on third lobe $= 2 \times \frac{1}{8} + 0.003 = 0.253$ inch.

The depth to which the drill can be fed into the work before withdrawing can sometimes be increased, especially when a turret drilling attachment is used and the drill is greater than ⅛ inch in diameter.

The space on the cam surface necessary for dropping the drill back is generally equal to the space necessary for revolving the turret. It is, therefore, advisable to use more than one drill when there is a sufficient number of empty holes in the turret, as it will not be necessary to resharpen the drills so frequently, and they will also be kept cooler.

Oil-pump Attachment for Turret Tools

When a good supply of oil to the cutting edge of the tool is necessary for drilling deep holes, the attachment *A* shown in Fig. 6 is used. To the right of the engraving the attachment is shown inserted in the turret, and to the left it is shown removed. In explaining how this attachment works we will refer to the line engraving, Fig. 8. The oil is brought through the pipe *a*, as shown, up into the tube *c*,

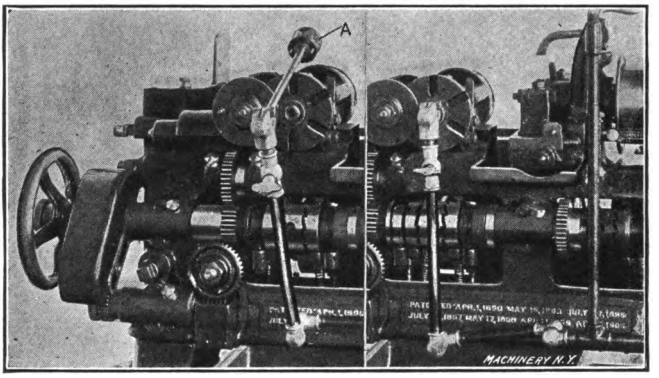

Fig. 6. No. OO Brown & Sharpe Automatic Screw Machine equipped with Oil-pumping Attachment for Turret Tools

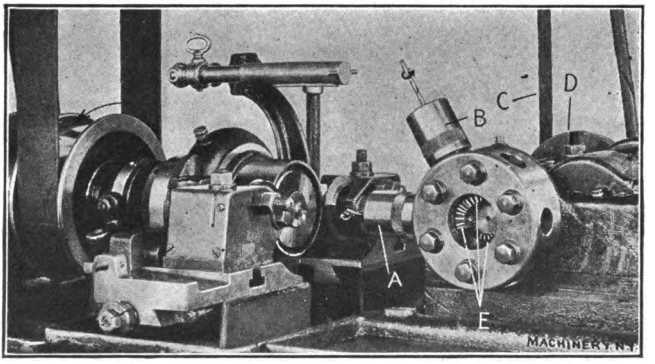

Fig. 7. No. 2 Brown & Sharpe Automatic Screw Machine equipped with Drilling Attachment

which is held in the split elbow *b*. The pipe *c* passes through the bronze bearing in the turret spindle to the oiling attachment *e*. This pipe has a slot *f*, 3/4 inch long by 3/32 inch wide, cut in the end facing the chuck. It is, therefore, obvious that oil can flow from this pipe only through the tools which are facing the chuck and in operation on the work. If any of the holes in the turret are not in use, a plug is inserted as shown at *g*. A clearer view of this plug is shown at *A*. The oiling attachment *e* is fastened to the turret by two small screws *i*. Thus the attachment rotates with the turret, bringing each

hole successively into line with slot *f*, where the oil can flow through. The outer shell of this oiling attachment is shown at *B*. Slots 1/2 inch long by 3/32 inch wide are cut in the hexagonal surfaces as shown, allowing the oil to pass through. The idea of having these slots elongated is to provide oil to the tools where it is impossible to have the oil pass through the hole in the center of the tool. A hole can be drilled close to the outside of the shank, and passing through the body, thus allowing the oil to penetrate to the cutting point of the tool.

Turret Drilling Attachment

In Fig. 7 is shown a No. 2 Brown & Sharpe automatic screw machine equipped with a turret-drilling attachment, two drill holders *A* and *B* being shown in position in the turret. This attachment is

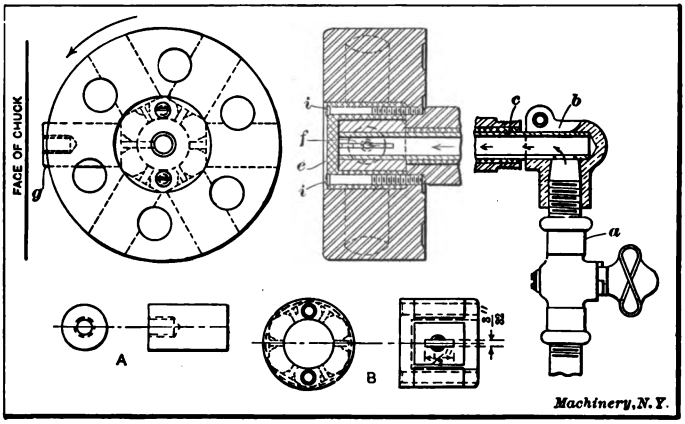

Fig. 8. Sectional View showing Construction of Oil-pumping Attachment for Turret Tools

driven from the overhead works by the ½-inch twisted belt *C*, the shaft passing through the turret connecting the pulley *D* with the bevel gears *E*. The manner in which this attachment is located and held in the turret is clearly shown in the sectional view Fig. 9. The pulley *D* is keyed to the shaft *F* and is also held in position with the nut *a*. Shaft *F* and bevel gear E_1 are made in one piece. The spindle of the drill holder is made of steel, hardened and ground, and runs in phosphor-bronze bearings.

The grooved pulley on the countershaft can be changed to increase or decrease the speed of the drill, as may be desired. The drill is revolved in the opposite direction to that in which the spindle and work are rotating, thus increasing the speed of the drill relative to the speed of the other tools. It is, therefore, obvious that the lobe on the cam for the drilling operation cannot be calculated from the speed of the spindle alone, but must also take into consideration the speed of the drilling attachment. To illustrate clearly the method of finding the number of revolutions required for drilling we will take a

practical example. Before proceeding with the calculation we will assume the following values for speeds, depth of hole, time, etc.:

Let speed of spindle = 1200 R.P.M.,

speed of drilling attachment = 900 R.P.M.,
number of seconds to make one piece = 20,
total number of revolutions to complete one piece = 400,
depth of hole plus amount to approach = $\frac{3}{8}$ inch,
diameter of drill = $\frac{1}{8}$ inch,
feed on drill = 0.0032 inch per revolution.

The total number of revolutions required for drilling, if the drilling attachment were not used, would be $= \frac{0.375}{0.0032} = 117$ revolutions.

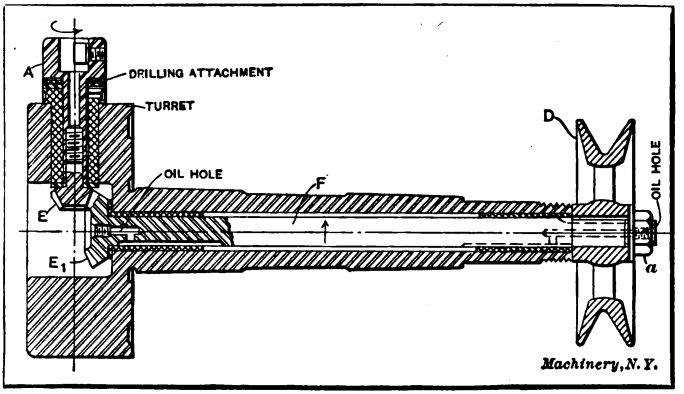

Fig. 9. Sectional View showing Construction of Drilling Attachment

The actual number of revolutions required for drilling when using the drilling attachment $= \frac{1200}{1200 + 900} \times 117 = 66.85$, or approximately, 67 revolutions.

Advantages of Turret Drilling Attachment

The following are three of the many advantages gained by using this attachment: First, the drill and the work are both given a rotary motion, which tends to produce a hole more straight than if the work alone were rotated; second, rotating the drill facilitates the removal of the chips from the hole and also allows the lubricant to penetrate to the cutting point; third, a suitable surface speed for the drill is obtained without increasing the cutting speed of the other tools in the turret.

It may also be mentioned that a spiral-fluted drill gives satisfactory results for drilling machine steel and brass when using this attachment; but for drilling brass where a long, curling chip is objectionable, the lips of the twist drill can be ground in, making the drill similar to a flat drill.

Cross-slide Drilling Attachment

It is sometimes found necessary to drill holes in a piece of work at right angles to the center line, or, in other words, across the piece. For this kind of work the cross-slide drilling attachment shown at *A* in Fig. 10 is found very serviceable. To apply this attachment to the cross-slide, the toolpost which carries the circular tool is removed and the attachment located in its place. The attachment is then held to the cross-slide by means of screw and nut *a*. The drill is held in a bushing in the spindle *b* by means of the headless screw shown. The two screws *c* are provided for taking up the wear in the bronze bearing. The small grooved pulley *d* is keyed to the spindle *b* and held by the nut and washer shown. The large grooved pulley *B* is located on the countershaft and drives the cross-slide drilling attachment through the medium of a ⅜- or ½-inch twisted belt, the size of the

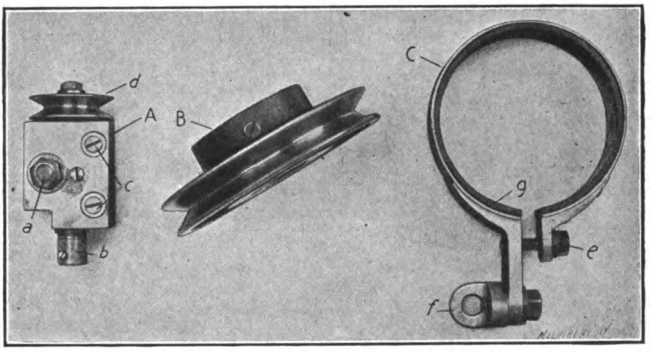

Fig. 10. Brown & Sharpe Cross-slide Drilling Attachment

belt depending on the machine to which the attachment is to be fitted. In cross-drilling it is necessary to stop the spindle and to hold it rigidly before the drill can operate. A brake shown at *C* for holding the spindle when drilling is used for this purpose. The brake proper is made from soft iron and has a strip of leather *g* attached to its inner surface, which grips the spindle firmly, preventing it from slipping. The cap-screw *e* is used for tightening the clamp on the pulley. The lug *f* is located on the pin which acts as a stop for the cross-slide tools.

It is obvious that when using a cross-slide drilling attachment, threading operations cannot be performed without the aid of a die and tap revolving attachment, as the spindle can rotate in one direction only. When using a revolving attachment in connection with the cross-drilling attachment, the threading attachment rotates the tap in the proper direction to release it from the work when the spindle is stopped. The tap is operated at one-half the spindle speed. Hence, for example, if a right-hand thread is being cut, the tap is rotated left-hand, advancing in the work when the spindle is running and retreating when the spindle is stopped. An opening die-holder is also

sometimes used for cutting external threads when a cross-drilling attachment is used.

The method of fitting up this attachment is as follows: The belt is removed from the pulley nearest the collet, and the band *C* expanded over the pulley. It is then fastened to the pin which acts as a stop for the cross-slide, and clamped to the pulley by cap-screw *e*. The dogs on the drum are then set to throw the clutch onto the pulley, which is clamped just before the drilling attachment advances toward the work. After the drilling operation has been completed and the drill retreats from the work, the clutch is thrown out and onto the other pulley and the other operations continued. The spindle is started and stopped practically instantaneously, but it is advisable to allow a moment's time, equivalent to about five revolutions, before and

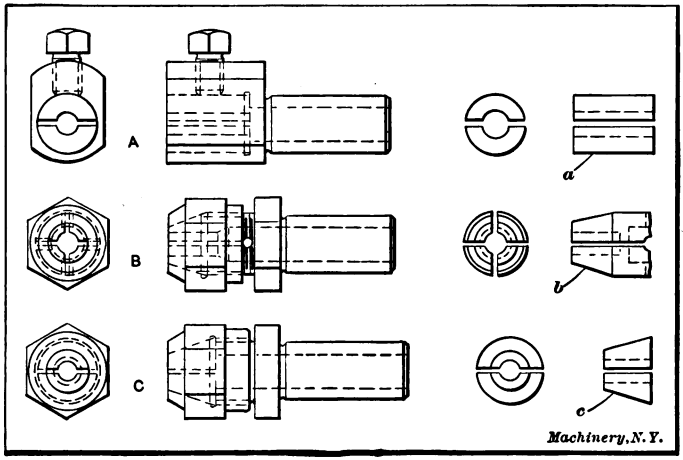

Fig. 11. Various Types of Drill Holders

after the drilling operation, for clearance. The drill should be ground with a more acute point-angle than for ordinary work, and should also be ground thin at the point to facilitate its starting into the work. The rise on the cam is similar to the rise for ordinary drilling, but the feed should be less. In most cases, for cross-drilling operations, it is an advantage to carry a guide bushing in the turret for locating the drill. Under this condition it is obvious that the work is drilled as if it were held in a jig, as the bushing is held in a floating holder that can be adjusted to produce the desired relation between the cross-hole and the outside diameter of the work.

Drill Holders

There are various types of drill holders used in the automatic screw machine, some of them being more complicated and expensive than is really necessary. The alignment of the turret holes with the spindle is nearly always perfect, and it is not necessary to have floating holders for holding a drill. At *A* in Fig. 11 is shown a common form of

TABLE III. FEEDS FOR HIGH-SPEED AND CARBON STEEL TWIST DRILLS

Diameter of Drill, Drill Gage or Inches	Brass Rod, Feed per Revolution	Machine Steel, Feed per Revolution	Tool Steel, Feed per Revolution	Diameter of Drill, Drill Gage or Inches	Brass Rod, Feed per Revolution	Machine Steel, Feed per Revolution	Tool Steel, Feed per Revolution
70	0.00070	0.00060	0.00050	9/32	0.0058	0.0052	0.0042
65	0.00075	0.00065	0.00055	5/16	0.0059	0.0055	0.0043
60	0.00080	0.00070	0.00060	11/32	0.0066	0.0058	0.0045
56	0.00120	0.00100	0.00080	3/8	0.0062	0.0060	0.0048
1/16	0.00180	0.00150	0.00100	13/32	0.0065	0.0062	0.0050
5/64	0.00250	0.00200	0.00120	7/16	0.0068	0.0065	0.0052
3/32	0.00250	0.00230	0.00150	15/32	0.0070	0.0068	0.0055
7/64	0.00300	0.00250	0.00180	1/2	0.0070	0.0070	0.0058
1/8	0.00320	0.00280	0.00200	17/32	0.0072	0.0072	0.0059
9/64	0.00350	0.00300	0.00230	9/16	0.0075	0.0075	0.0060
5/32	0.00380	0.00320	0.00250	19/32	0.0078	0.0078	0.0062
11/64	0.00400	0.00350	0.00280	5/8	0.0080	0.0079	0.0063
3/16	0.00420	0.00400	0.00300	21/32	0.0082	0.0080	0.0064
13/64	0.00450	0.00420	0.00320	11/16	0.0085	0.0082	0.0065
7/32	0.00480	0.00450	0.00350	3/4	0.0090	0.0083	0.0068
15/64	0.00500	0.00480	0.00380	13/16	0.0095	0.0085	0.0069
1/4	0.00550	0.00500	0.00400	7/8	0.0100	0.0088	0.0070

drill holder. This drill holder is serviceable and cheaply made. As can be seen, it is slabbed down on the sides to take up as little space as possible when working in conjunction with the cross-slide tools. The hole for the bushing is laid off eccentric to the main body of the holder, which allows enough stock on the upper portion to hold the set-screw. A plain bushing as shown at *a* is used. This bushing holds the drill very effectively. At *B* is shown a more expensive holder which is sometimes used for holding reamers and counterbores for operating on a piece which has previously been drilled concentric. This holder is made solid and then slotted as shown. The bushing part of the holder is shown at *b*. At *C* is shown a holder somewhat similar to that shown at *B*, but instead of the shank and drill holder

being in one piece, a separate bushing is used. This holder is easier to set concentric with the work, but the extra cost prohibits its use to a great extent. The bushing as used in this holder is shown at *c*. For ordinary work the holder shown at *A* is recommended.

Drilling Speeds and Feeds

When drilling in the Brown & Sharpe automatic screw machines, the best results are generally obtained by giving the drills light feeds and high peripheral velocities. High-speed steel drills are commendable for drilling Norway iron, machine steel, tool steel, etc., but the ordinary carbon steel drills are suitable for brass and similar materials when the surface speed does not exceed that given in the following. The surface speeds here given for carbon and high-speed steel drills have been found satisfactory for the materials specified:

SPEEDS FOR ORDINARY CARBON STEEL DRILLS

Material	Surface Speed in Feet per Minute
Brass (ordinary quality)	160—180
Gun-screw iron	60— 70
Norway iron and machine steel	50— 60
Drill rod and tool steel	30— 40

SPEEDS FOR HIGH-SPEED STEEL DRILLS

Material	Surface Speed in Feet per Minute
Gun-screw iron	100—125
Norway iron and machine steel	80—100
Drill rod and tool steel	50— 60

Feeds for high-speed and ordinary carbon steel twist drills are given in Table III. The feeds given are for general work, but when the surface speed is not high the feed on the drill can be increased somewhat. It is found to be more satisfactory in general practice to keep the feed down, as a more straight hole can be produced than if the drill is forced.

Drills from 1/8 inch to 3/16 inch are capable of standing the heaviest feeds in proportion to their diameter, and when a hole does not pass through the work a ⅛-inch drill has been found to stand a feed of 0.016 inch per revolution when drilling brass. Feeds as heavy as this are not recommended, because concentric holes cannot be produced when the drill is forced to such an extent.

CHAPTER II

COUNTERBORING AND REAMING OPERATIONS

As a rule, more trouble is experienced in applying counterbores to the work on automatic machines than is experienced with any other cutting tool. This is probably due to the fact that counterbores are generally improperly made for the work on which they are to operate. Generally speaking, there are several reasons for the unsuccessful working of counterbores, some of which may be summed up as follows:

1. Too many cutting edges, not allowing enough chip space and also not providing for sufficient lubrication.
2. Too much cutting surface in contact with the work.
3. Insufficient clearance on the periphery of the teeth.
4. Improper location of the cutting edges relative to the center.
5. Improper method of holding the counterbore.
6. Improper grinding of the cutting edges.
7. Too weak a cross-section.
8. The use of a feed and speed in excess of what the tool will stand.

For general work, and especially for automatic work where the counterbore cannot be withdrawn when it plugs up with chips and seizes in the work, this tool should not have more than three cutting teeth. The periphery of the teeth should be backed off eccentrically, and the body of the counterbore should taper towards the back. The amount of taper generally varies from 0.020 to 0.040 inch per foot. The relation of the cutting edge to the center has an important bearing on the efficiency of the tool. For deep counterboring, where the difference between the diameter of the teat and the body of the counterbore is great, the cutting edge should never be located ahead of the center; in fact, if it is located a little below the center far better results are obtained. This rule is only general, of course, as the material to a considerable extent governs the location of the cutting edges.

Location of the Cutting Edges

At *A* in Fig. 12 is shown a three-tooth counterbore with its cutting edges located ahead of the center. Locating the cutting edge ahead of the center is advisable when the counterbore is to be used as a facing tool, or used for counterboring brass, and it is not required to extend into the work to a depth greater than its diameter, but it should preferably be used for facing operations only. If the counterbore is made in this manner and used on steel, the cutting teeth have a tendency to force the chips against the surface of the work. Consequently, when it is not properly lubricated, the work and counterbore become heated, and cause the chips to seize, thus producing poor work and, generally, a broken counterbore.

At *B* are shown the teeth cut radially to the center. For general work this is the best location for the cutting edges relative to the center. There is not the same tendency to force the chips against the surface of the work. Teeth cut radially to the center are suitable for either brass or steel work, but when used on steel, it is preferable to have the teeth cut spirally. A spiral which will give a rake of from 10 to 15 degrees generally gives the best results.

At *C* are shown the teeth cut below the center. This is the proper location for the cutting edges of the teeth where the difference between the diameter of the teat and the body of the counterbore is not very great, and where the counterbore is to extend into the work to a depth greater than its diameter. This, as can be seen, gives a lip to the counterbore which has a tendency to lift the chips from the cutting surface of the work, thus preventing them from seizing.

Various Types of Counterbores

When counterboring a hole where a large amount of material is to be removed, and where the counterbore is to extend into the work to

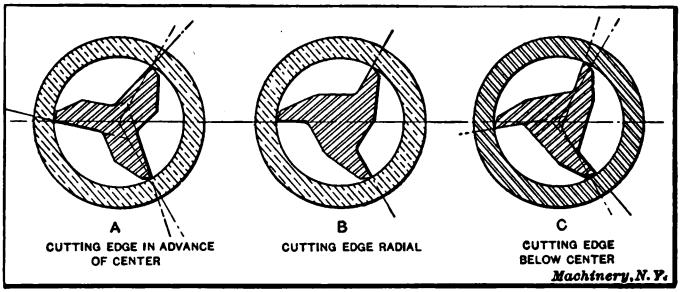

Fig. 12. Location of the Cutting Edges for Various Conditions

a depth greater than its diameter, it is generally advisable to rough out the hole to the diameter of the body of the counterbore with a three-fluted drill, such as shown at *A*, Fig. 13. Then the counterbore is used only for squaring up the shoulder at the bottom of the hole. This method is especially advisable when counterboring machine or tool steel.

At *B* is shown a counterbore which can sometimes be used to advantage on brass work, but which is not recommended for steel. It is made on the same principle as a flat drill with the exception that the teat has no cutting edges. At *C* is shown another counterbore for brass work, which has three cutting edges, and at *D* is shown a counterbore for steel work, having its teeth cut spirally. Teeth cut on a spiral which will produce a rake angle of 10 to 15 degrees are generally found suitable for machine or tool steel. Counterbores of the type shown at *C* and *D* should have inserted leaders or teats to facilitate their re-sharpening.

At *E* is shown a counterbore which is recommended for work having complicated shapes, or requiring to have two or more diameters finished with the same tool. This tool is backed off helically as shown,

thus allowing it to be ground and still retain its initial shape and size. The backing off is accomplished on the lathe in the following manner: The lathe is geared up to cut six or eight threads per inch, depending on the diameter of the counterbore and the amount of clearance required. The counterbore, after being turned to the required dimensions, is milled as shown at *b*. It is then placed on the centers of the lathe, being driven by a dog, and a facing tool used for backing it off. The backing off is accomplished by pulling on the belt for each cut,

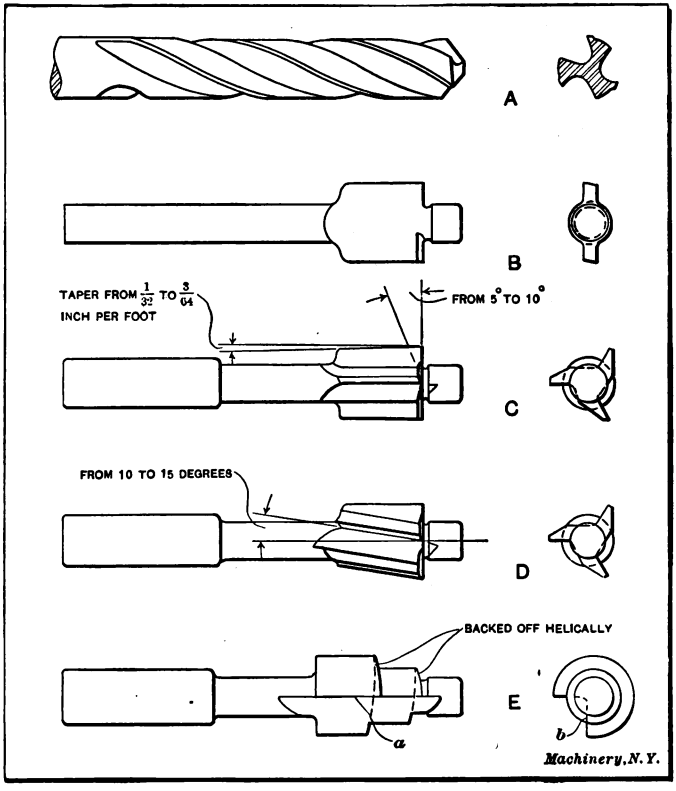

Fig. 13. Various Types of Counterbores

starting and finishing at the groove *b* until the backing off is completed. Where a backing-off attachment which is operated by a removable cam is available, this tedious operation can be done with greater ease and rapidity.

The counterbores described are for making pieces in which the hole extends through the work or to a depth which permits using a leader or teat; but for work in which the hole bottoms, that is, does not extend far enough into or through the work, these counterbores could not be used. The ordinary method used in producing holes which bottom is to use flat drills and combination counterbores and facing tools.

Flat Drills and Combination Counterbores

At *A* in Fig. 14 is shown a flat drill which is used for roughing out a hole having one diameter, and at *B* is shown the counterbore or facing tool which is used for squaring it up. The cutting edge *a* on the tool should be set about 0.1 times the diameter ahead of the center, and the thickness of the blade *b* should be about one-eighth of the diameter. At *C* is shown a flat drill or counterbore for producing

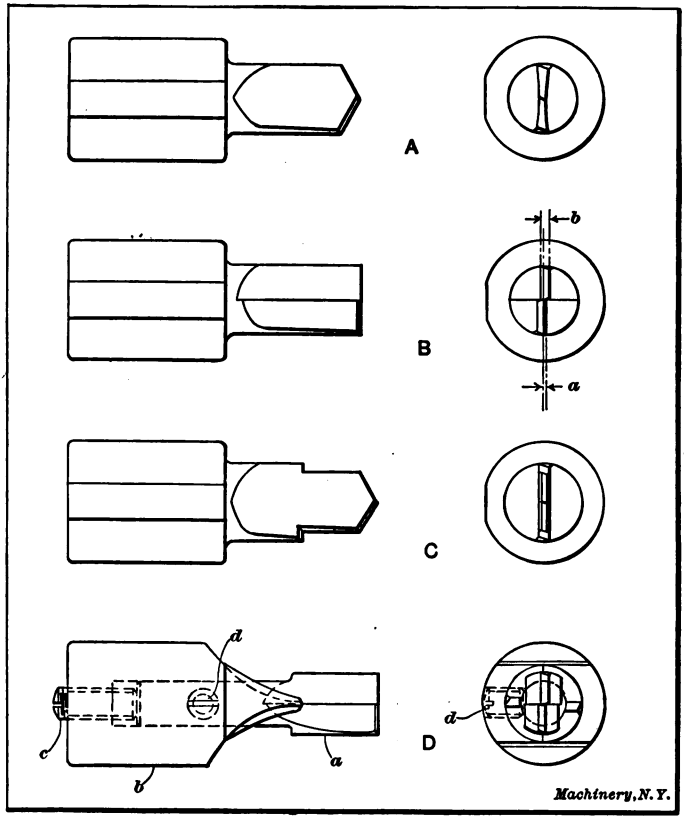

Fig. 14. Flat Drills and Combination Counterbores

a hole having two diameters, and at *D* is shown the combination counterbore and facing tool for squaring it up. This counterbore is adjustable, the part *a* being adjusted with relation to part *b* by means of the headless screw *c*, thus governing the distance between the shoulders, the headless screw *d* being used to prevent the part *a* from rotating. When the part *a* projects out from the part *b* a distance greater than one-half its diameter, care should be taken to have the shank a good fit in part *b*. These counterbores can be used for either brass or steel work, but for steel work it is preferable to use a spiral-

fluted drill for roughing out the hole, instead of a flat drill, as the material can be removed with greater ease and rapidity.

Speeds for Counterbores

The surface speed at which a counterbore can be worked is slightly less than the surface speed used for drilling. The surface speeds given below are recommended for counterbores made from carbon and high-speed steel.

SPEEDS FOR COUNTERBORES MADE FROM CARBON STEEL

Material	Surface Speed in Feet per Minute
Brass (ordinary quality)	150-160
Gun-screw iron	50-60
Norway iron and machine steel	40-50
Drill rod and tool steel	30-35

SPEEDS FOR COUNTERBORES MADE FROM HIGH-SPEED STEEL

Material	Surface Speed in Feet per Minute
Brass (ordinary quality)	180-200
Gun-screw iron	80-90
Norway iron and machine steel	70-80
Drill rod and tool steel	45-50

Feeds for Counterbores

The method of holding a counterbore when applying it to the work, and the strength of the cross-section in proportion to the width of the chip being removed, governs to a considerable extent the amount of feed to be given. The material being cut and the depth to which the counterbore penetrates into the work, also have an important bearing on the rate of feed. These conditions should be taken into consideration when using the feeds given in Table IV. These feeds are for counterbores having three cutting edges, but for counterbores having one cutting edge the feed should be decreased from 40 to 50 per cent, and for two cutting edges, from 15 to 20 per cent. It is obvious that no definite rule can be laid down in regard to the exact feed to use, on account of the number of conditions which govern the rate of feed. The feeds given in Table IV should be used only when the counterbore penetrates from one-half to three-quarters of its diameter into the work. When the counterbore penetrates to a greater distance the feed should be decreased from 15 to 25 per cent. It is good practice to always drop the counterbore back after it has penetrated to a depth equal to half its diameter, to remove the chips, and to cool and lubricate it. The same method can be used for dropping back the counterbore as was described in connection with deep-hole drilling in the preceding chapter.

Holders for Counterbores

For counterbores having leaders, a rigid holder should not be used, as the leader will follow the hole previously drilled or reamed, and if the counterbore is not allowed to float, it will produce poor work, and a broken tool will sometimes be the result. At *A* in Fig. 15 is shown

TABLE IV. FEEDS FOR COUNTERBORES MADE FROM HIGH-SPEED AND CARBON STEEL

1/32-inch Chip				3/32-inch Chip				1/16-inch Chip			
Diameter of Counterbore in Inches	Brass Rod, Feed per Revolution	Mach. Steel, Feed per Revolution	Tool Steel, Feed per Revolution	Diameter of Counterbore in Inches	Brass Rod, Feed per Revolution	Mach. Steel, Feed per Revolution	Tool Steel, Feed per Revolution	Diameter of Counterbore in Inches	Brass Rod, Feed per Revolution	Mach. Steel, Feed per Revolution	Tool Steel, Feed per Revolution
1/8	0.0025	0.0018	0.0015	3/8	0.0040	0.0032	0.0020	9/16	0.0045	0.0035	0.0025
3/16	0.0030	0.0023	0.0020	7/16	0.0045	0.0035	0.0025	5/8	0.0048	0.0038	0.0028
1/4	0.0035	0.0030	0.0025	1/2	0.0050	0.0040	0.0030	11/16	0.0050	0.0040	0.0030
5/16	0.0045	0.0040	0.0030	9/16	0.0055	0.0045	0.0035	3/4	0.0055	0.0043	0.0032
3/8	0.0050	0.0045	0.0035	5/8	0.0060	0.0050	0.0040	13/16	0.0060	0.0045	0.0035
7/16	0.0060	0.0050	0.0038	11/16	0.0070	0.0055	0.0045	7/8	0.0065	0.0048	0.0038
1/2	0.0075	0.0052	0.0040	7/8	0.0075	0.0060	0.0050	15/16	0.0070	0.0050	0.0040
1/16-inch Chip				**1/8-inch Chip**				**1/4-inch Chip**			
1/4	0.0030	0.0028	0.0020	1/2	0.0050	0.0042	0.0025	11/16	0.0040	0.0030	0.0020
5/16	0.0035	0.0030	0.0025	9/16	0.0052	0.0045	0.0030	3/4	0.0042	0.0032	0.0022
3/8	0.0040	0.0035	0.0028	5/8	0.0055	0.0048	0.0032	13/16	0.0045	0.0035	0.0025
7/16	0.0045	0.0038	0.0030	11/16	0.0058	0.0050	0.0035	7/8	0.0048	0.0038	0.0030
1/2	0.0050	0.0040	0.0035	3/4	0.0060	0.0055	0.0040	15/16	0.0050	0.0040	0.0032
9/16	0.0055	0.0045	0.0038	13/16	0.0065	0.0058	0.0045	1	0.0050	0.0045	0.0035
5/8	0.0060	0.0050	0.0040	7/8	0.0070	0.0060	0.0050	.....	.....	.....	.....

a floating holder which will be found very serviceable for the conditions just mentioned. The sleeve or shank *a* is made to fit the turret and is bored out from 1/32 to 1/16 inch larger in diameter than the shank of the holder *b*. The holder *b* is kept from turning by the driving pin *c*, which is made a driving fit in the part *b* and a loose fit in the part *a*. The hole in the part *a* should be about 1/32 inch in diameter larger than the pin *c*. The two headless screws *d* are used for adjusting the counterbore so that it will enter easily into the drilled hole. They also help to keep the holder *b* from turning. It is

good practice, when possible, to chamfer the hole so that the leader will enter easily. The counterbore is held by the split bushing *e* and set-screw *f*. If this holder is properly made and set it will be found to give good results for general work.

At *B* in Fig. 15 is shown a "floating" holder for holding the flat counterbore shown. This holder is not an actual floating holder, but would be better named an adjustable holder. It is made adjustable so that the tool can be set concentric with the center of the work. After adjusting, the part *a* is held tightly against the part *b* by the cap-screws *c*. The clearance holes in the part *a* for the cap-screws *c* are made about 1/16 inch in diameter larger than the body of the screw. The counterbore is held in the part *a* by set-screw *d*. This holder is

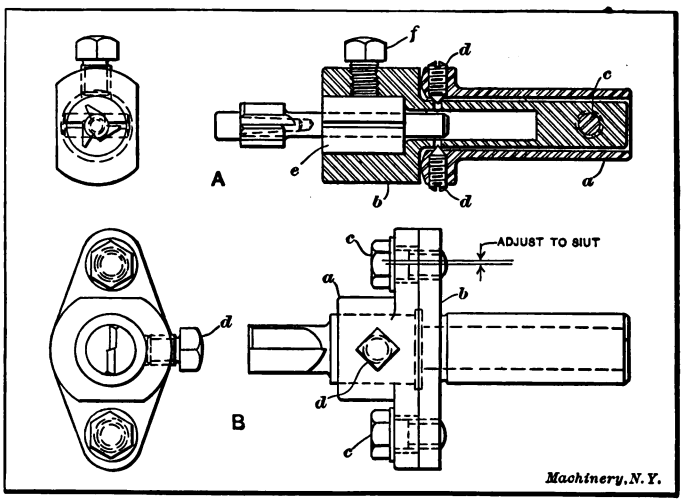

Fig. 15. Method of Holding Counterbores for Various Conditions

also found very serviceable for holding a counterbore when the hole to be counterbored penetrates into the work to a distance greater than its diameter and a chucking drill has been used to rough it out.

Reaming and Reamers

When it is necessary to make a perfectly round and accurate hole in the work, a reamer is used, the drilled hole being left slightly smaller to allow enough material for the reamer to true it up and bring it to the desired size. It is always advisable not to leave any more material to be removed by the reamer than is absolutely necessary. For general work the amounts given in the following list will give good results for reamers ranging in diameter from 1/8 to 3/8 inch. For reamers over 3/8 inch diameter, a drill 1/64 inch less in diameter is generally used, and this would leave from 0.012 to 0.015 inch to remove on the diameter, as it is obvious that a drill will cut slightly larger than its nominal size.

TABLE OF DIAMETERS OF HOLES DRILLED PREVIOUS TO REAMING

Diameter of Reamer in Inches	Diameter of Hole previous to Reaming, in Inches
1/8	0.120
3/16	0.182
1/4	0.242
5/16	0.302
3/8	0.368

There are various reasons for the inefficient working of a reamer, some of which are the following:

1. Chattering, which results when the teeth are evenly spaced.

2. Chips clinging to the teeth, which action results when high periphery velocities are used, with insufficient clearance.

TABLE V. FEEDS FOR REAMERS MADE FROM HIGH-SPEED AND CARBON STEEL

Diameter of Reamer in Inches	Brass Rod, Feed per Revolution	Machine Steel, Feed per Revolution	Tool Steel, Feed per Revolution
1/8	0.007	0.004	0.002
5/32	0.008	0.004	0.003
3/16	0.009	0.005	0.004
7/32	0.010	0.006	0.005
1/4	0.011	0.007	0.006
9/32	0.012	0.008	0.007
5/16	0.013	0.009	0.008
11/32	0.014	0.010	0.009
3/8	0.015	0.011	0.010
13/32	0.016	0.012	0.011
7/16	0.017	0.013	0.011
15/32	0.018	0.014	0.012
1/2	0.020	0.015	0.012

3. Expanding and contracting of the hole, which is caused by too heavy feed and insufficient clearance on the cutting edges.

4. Enlarged and tapered holes, due to holding the reamer rigid instead of floating.

There are various methods adopted to prevent reamers from chattering, but the unequal spacing of the teeth has been found the most satisfactory and inexpensive. For machine reamers varying from 1/8 to 1/4 inch, three cutting edges are sometimes used, but the difficulty encountered in measuring their diameter with micrometers limits their use to a certain extent. As a general rule, therefore, four and six cutting edges are used on reamers varying from 1/8 inch to 3/8 inch, and 8 to 12 cutting edges on reamers varying from 3/8 inch to 7/8 inch.

The clinging of chips to the teeth is generally due to high periphery velocities and improper lubrication. Insufficient clearance of the cutting edges also heats the work to a considerable extent, which causes the chips to cling. The clinging of the chips is more noticeable on

steel containing a small percentage of carbon than it is on brass or steels which contain a high percentage of carbon.

Reamers are generally made slightly tapering towards the back; a taper varying from 0.002 to 0.005 inch per foot is generally used, and a less taper should be used for brass than steel, as brass work, especially thin tubing, contracts and expands more readily than steel, so that, if a perfect hole is desired, the reamer should be tapered but slightly. For reaming machine steel a rose reamer is generally used, as it has been found satisfactory for producing straight and perfect holes. This reamer tapers towards the back and is not relieved on the periphery of the cutting edges, the end of the reamer only being backed off.

The cutting edges of reamers are generally cut on the center (radial) for steel, but for brass work they are sometimes cut slightly ahead of the center, which produces a scraping action, and makes a smooth cut.

Reaming Feeds and Speeds

The surface speeds used for reaming should be slightly less than those used for counterboring, as the reamer generally penetrates to a greater depth and has more cutting surface in contact with the work, which tends to produce excessive heating of the work and reamer, resulting in chips clinging to the cutting edges, with rough and inaccurate work as a consequence. When a good supply of lard oil is used, the following surface speeds will be found satisfactory.

SPEEDS FOR REAMERS MADE FROM CARBON STEEL

Material	Surface Speed in Feet per Minute
Brass (ordinary quality)	120-125
Gun-screw iron	35-40
Norway iron and machine steel	30-35
Drill rod and tool steel	20-25

SPEEDS FOR REAMERS MADE FROM HIGH-SPEED STEEL

Material	Surface Speed in Feet per Minute
Brass (ordinary quality)	150-160
Gun-screw iron	65-75
Norway iron and machine steel	50-60
Drill rod and tool steel	30-40

The feeds for reamers given in Table V will be found suitable for general work, when no more material is removed on the diameter than previously stated. When reaming thin tubing, especially brass, the feed should be decreased somewhat.

The method used for holding a reamer when applying it to the work governs to a considerable extent the quality of the hole produced. When reaming a deep hole, if the reamer is held rigidly, it will nearly always produce a hole which will be tapered and large in diameter.

At *A* in Fig. 16 is shown a floating holder which is sometimes used. This holder is cheaply made, but is not a commendable holder for automatic screw machine work, although it can sometimes be used to ad-

TABLE IV. FEEDS FOR COUNTERBORES MADE FROM HIGH-SPEED AND CARBON STEEL

Diameter of Counterbore in Inches	Brass Rod, Feed per Revolution	Mach. Steel, Feed per Revolution	Tool Steel, Feed per Revolution
1/32-inch Chip			
1/8	0.0025	0.0018	0.0015
3/16	0.0030	0.0023	0.0020
1/4	0.0035	0.0030	0.0025
5/16	0.0045	0.0040	0.0030
3/8	0.0050	0.0045	0.0035
7/16	0.0060	0.0050	0.0038
1/2	0.0075	0.0052	0.0040
3/32-inch Chip			
3/8	0.0040	0.0032	0.0020
7/16	0.0045	0.0035	0.0025
1/2	0.0050	0.0040	0.0030
9/16	0.0055	0.0045	0.0035
5/8	0.0060	0.0050	0.0040
11/16	0.0070	0.0055	0.0045
7/8	0.0075	0.0060	0.0050
1/16-inch Chip			
1/4	0.0030	0.0028	0.0020
5/16	0.0035	0.0030	0.0025
3/8	0.0040	0.0035	0.0028
7/16	0.0045	0.0038	0.0030
1/2	0.0050	0.0040	0.0035
9/16	0.0055	0.0045	0.0038
5/8	0.0060	0.0050	0.0040
1/8-inch Chip			
1/2	0.0050	0.0042	0.0025
9/16	0.0052	0.0045	0.0030
5/8	0.0055	0.0048	0.0032
11/16	0.0058	0.0050	0.0035
3/4	0.0060	0.0055	0.0040
13/16	0.0065	0.0058	0.0045
7/8	0.0070	0.0060	0.0050
3/16-inch Chip			
9/16	0.0045	0.0035	0.0025
5/8	0.0048	0.0038	0.0028
11/16	0.0050	0.0040	0.0030
3/4	0.0055	0.0043	0.0032
13/16	0.0060	0.0045	0.0035
7/8	0.0065	0.0048	0.0038
15/16	0.0070	0.0050	0.0040
1/4-inch Chip			
11/16	0.0040	0.0030	0.0020
3/4	0.0042	0.0032	0.0022
13/16	0.0045	0.0035	0.0025
7/8	0.0048	0.0038	0.0030
15/16	0.0050	0.0040	0.0032
1	0.0050	0.0045	0.0035
.....	.....	.....	.....

a floating holder which will be found very serviceable for the conditions just mentioned. The sleeve or shank *a* is made to fit the turret and is bored out from 1/32 to 1/16 inch larger in diameter than the shank of the holder *b*. The holder *b* is kept from turning by the driving pin *c*, which is made a driving fit in the part *b* and a loose fit in the part *a*. The hole in the part *a* should be about 1/32 inch in diameter larger than the pin *c*. The two headless screws *d* are used for adjusting the counterbore so that it will enter easily into the drilled hole. They also help to keep the holder *b* from turning. It is

good practice, when possible, to chamfer the hole so that the leader will enter easily. The counterbore is held by the split bushing *e* and set-screw *f*. If this holder is properly made and set it will be found to give good results for general work.

At *B* in Fig. 15 is shown a "floating" holder for holding the flat counterbore shown. This holder is not an actual floating holder, but would be better named an adjustable holder. It is made adjustable so that the tool can be set concentric with the center of the work. After adjusting, the part *a* is held tightly against the part *b* by the cap-screws *c*. The clearance holes in the part *a* for the cap-screws *c* are made about 1/16 inch in diameter larger than the body of the screw. The counterbore is held in the part *a* by set-screw *d*. This holder is

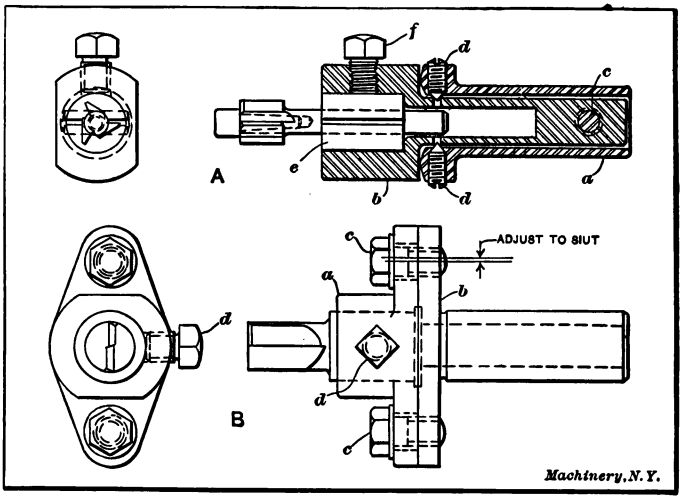

Fig. 15. Method of Holding Counterbores for Various Conditions

also found very serviceable for holding a counterbore when the hole to be counterbored penetrates into the work to a distance greater than its diameter and a chucking drill has been used to rough it out.

Reaming and Reamers

When it is necessary to make a perfectly round and accurate hole in the work, a reamer is used, the drilled hole being left slightly smaller to allow enough material for the reamer to true it up and bring it to the desired size. It is always advisable not to leave any more material to be removed by the reamer than is absolutely necessary. For general work the amounts given in the following list will give good results for reamers ranging in diameter from 1/8 to 3/8 inch. For reamers over 3/8 inch diameter, a drill 1/64 inch less in diameter is generally used, and this would leave from 0.012 to 0.015 inch to remove on the diameter, as it is obvious that a drill will cut slightly larger than its nominal size.

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5/16	0.302
3/8	0.368

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1. Chattering, which results when the teeth are evenly spaced.

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3/16	0.009	0.005	0.004
7/32	0.010	0.006	0.005
1/4	0.011	0.007	0.006
9/32	0.012	0.008	0.007
5/16	0.013	0.009	0.008
11/32	0.014	0.010	0.009
3/8	0.015	0.011	0.010
13/32	0.016	0.012	0.011
7/16	0.017	0.013	0.011
15/32	0.018	0.014	0.012
1/2	0.020	0.015	0.012

3. Expanding and contracting of the hole, which is caused by too heavy feed and insufficient clearance on the cutting edges.

4. Enlarged and tapered holes, due to holding the reamer rigid instead of floating.

There are various methods adopted to prevent reamers from chattering, but the unequal spacing of the teeth has been found the most satisfactory and inexpensive. For machine reamers varying from 1/8 to 1/4 inch, three cutting edges are sometimes used, but the difficulty encountered in measuring their diameter with micrometers limits their use to a certain extent. As a general rule, therefore, four and six cutting edges are used on reamers varying from 1/8 inch to 3/8 inch, and 8 to 12 cutting edges on reamers varying from 3/8 inch to 7/8 inch.

The clinging of chips to the teeth is generally due to high periphery velocities and improper lubrication. Insufficient clearance of the cutting edges also heats the work to a considerable extent, which causes the chips to cling. The clinging of the chips is more noticeable on

steel containing a small percentage of carbon than it is on brass or steels which contain a high percentage of carbon.

Reamers are generally made slightly tapering towards the back; a taper varying from 0.002 to 0.005 inch per foot is generally used, and a less taper should be used for brass than steel, as brass work, especially thin tubing, contracts and expands more readily than steel, so that, if a perfect hole is desired, the reamer should be tapered but slightly. For reaming machine steel a rose reamer is generally used, as it has been found satisfactory for producing straight and perfect holes. This reamer tapers towards the back and is not relieved on the periphery of the cutting edges, the end of the reamer only being backed off.

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Brass (ordinary quality)	120-125
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Norway iron and machine steel	30-35
Drill rod and tool steel	20-25

SPEEDS FOR REAMERS MADE FROM HIGH-SPEED STEEL

Material	Surface Speed in Feet per Minute
Brass (ordinary quality)	150-160
Gun-screw iron	65-75
Norway iron and machine steel	50-60
Drill rod and tool steel	30-40

The feeds for reamers given in Table V will be found suitable for general work, when no more material is removed on the diameter than previously stated. When reaming thin tubing, especially brass, the feed should be decreased somewhat.

The method used for holding a reamer when applying it to the work governs to a considerable extent the quality of the hole produced. When reaming a deep hole, if the reamer is held rigidly, it will nearly always produce a hole which will be tapered and large in diameter.

At *A* in Fig. 16 is shown a floating holder which is sometimes used. This holder is cheaply made, but is not a commendable holder for automatic screw machine work, although it can sometimes be used to ad-

vantage on the hand screw machine. One of the disadvantages of this reamer holder is that the reamer drops down as shown at *a* if much clearance is allowed between the diameter of the reamer shank and the diameter of the hole, thus preventing the reamer from entering easily into the work, which generally results in a broken reamer.

At *B* is shown a more efficient holder, especially for deep hole reaming. The reamer is guided at the rear by a cone-pointed screw *b*, and is kept from rotating and is guided at the same time by the two cone-pointed screws *c*. By means of these screws, the reamer can be set so

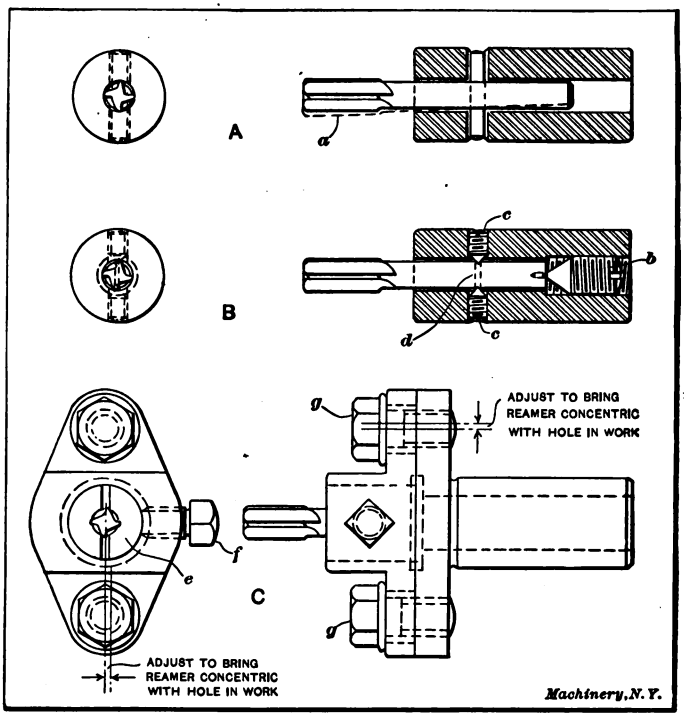


Fig. 16. Method of Holding Reamers for Various Conditions

that it will enter the drilled hole easily, and at the same time be allowed to adjust itself to correspond to the eccentricity of the hole in the work. The small hole *d* is drilled through the shank of the reamer, allowing the cone-pointed screws to enter. This holder will be found very satisfactory for holding reamers when it is not necessary to remove an excessive amount of material. At *C* is shown a floating holder which is used for reaming shallow holes. The reamer is held rigidly by a split bushing and set-screw *f*. The reamer is set concentric with the hole in the work by loosening the cap-screws *g* and then locating it in the hole by the bevel or rounded corners on the end of the reamer.

CHAPTER III

RECESSING TOOLS AND OPERATIONS

In this chapter, recessing tools and recessing operations will be described. The practice outlined is that generally accepted, and when used with discretion satisfactory results will be obtained. The speeds and feeds, of course, are liable to some variation on account of the conditions which govern them, but the feeds given are not exceedingly high and can be used to advantage in the majority of cases.

Three different types of recessing tool holders, commonly called swing tools, are described, but it will, of course, be seen that with slight modifications tool-holders of the description given can be used for various classes of work. Three types of recessing tools are also shown. These are suited for three different conditions, namely, for chamfering operations, for recessing operations, and for special conditions—that is, the third tool is used when the hole in the work is so small as not to permit the use of either of the other tools. Explicit instructions are also given for laying out cams for chamfering and recessing operations.

Recessing and Recessing Tools

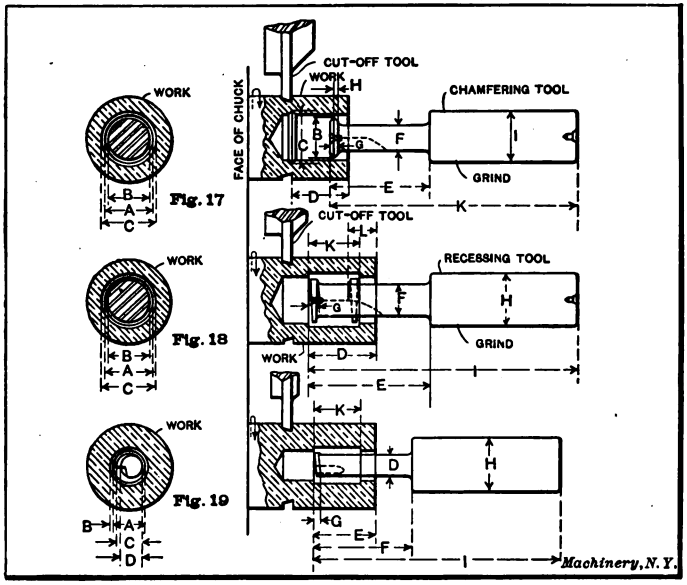
When it is necessary to chamfer a hole in each end of a piece, a recessing or so-called "internal" chamfering tool is used, which eliminates a second operation. A recessing tool which works on the same principle as an ordinary boring-tool is used for chambering or relieving a hole in the center, that is, just leaving a bearing surface at each end. The recessing or chamfering operation should always precede the reaming operation, so that all burrs thrown into the hole by the recessing tool will be removed by the reamer. A recessing or chamfering tool should be operated from the front cross-slide whenever possible, for the following reasons: In the first place, it is generally more convenient to make the necessary adjustments; in the second place, turning the tool upside down allows the chips to drop to the bottom of the hole where they are easily removed, thus allowing the tool to work with less obstruction; and in the third place, the recessing tool can be more conveniently operated from the front cross-slide, by means of the rising block used in connection with the forming tool holder. The regular rising block, however, is removed and a special rising block substituted, which has a cam attached, used for operating the recessing tool holders.

If, on the other hand, the recessing tool holder is operated from the rear cross-slide, the recessing either must be done when the spindle is running backwards, or else it will be necessary to make a special circular tool holder, in which the distance from the hole through which the screw is inserted to hold the circular tool, to the top face of the

cross-slide is of a less height than that ordinarily used on the rear cross-slide.

In cutting the finished piece from the bar after recessing, the feed should be decreased on the cut-off tool, so that the piece will be severed without leaving a burr where the two cuts meet. Decreasing the feed from 0.001 to 0.0005 inch per revolution is generally found sufficient.

At *A* in Fig. 20 is shown a recessing tool which is used for chamfering, and at *B* is shown a tool which is used for chambering. This latter tool removes the superfluous material in a similar manner to an ordinary boring-tool.



Figs. 17, 18 and 19. Diagrams illustrating the Method of Determining Proportions for Chamfering and Recessing Tools

The chamfering tool shown at *A* is not backed off, as it is smaller in diameter than the hole in the work, which gives it sufficient periphery clearance. For brass work, the cutting edge is cut radial as shown, or sometimes below the center when less clearance is necessary, as shown by the dotted line *a*, but for steel work it is cut above the center a distance equal to 0.1 of the diameter. The included angle β of the cutting edge is made as required, the angle usually being about 90 degrees.

The recessing or boring tool shown at *B* has its sides helically relieved, giving a clearance angle of from 5 to 8 degrees, which is found satisfactory for ordinary work. For brass work this tool is cut on the center or below, as shown by the dotted line *b*, and for steel work the same as already stated for chamfering tool *A*.

Where the hole in the work is of such a diameter that a tool made similar to those shown at *A* and *B* would be too slender to do efficient work, one similar to that shown at *C* and *D* can be used. The diameter of the cutting end of this tool need only be about 0.008 to 0.012 inch smaller than the hole. The distance *a* should be about 0.015 inch greater than the depth of the recess, and *b*, of course, will equal ½ *a*. The amount *c* that the cutting edge is cut below the center, should be enough to give the tool sufficient negative rake for brass, but for steel it should be cut 0.1 of the diameter above the center.

A good method of making this tool is as follows: Take a piece of drill rod of a diameter equal to the diameter of the shank required

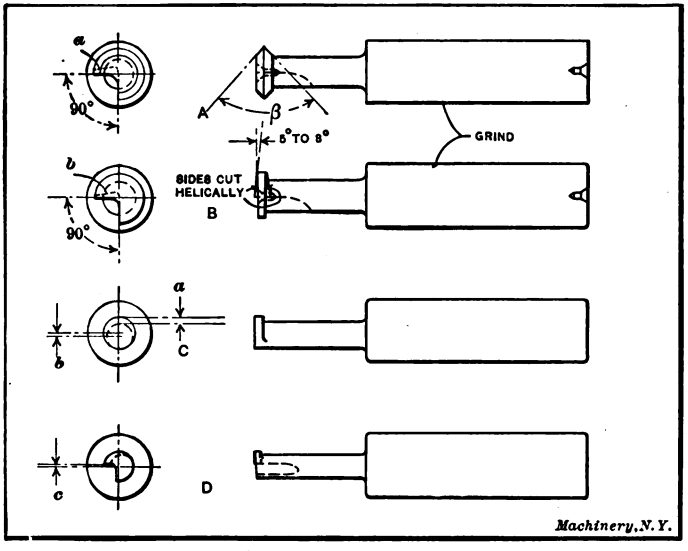


Fig. 20. Various Types of Recessing Tools

and insert it in a draw-in chuck held in a bench or other suitable lathe. Turn down the body of the tool to the diameter required, then remove the tool from the chuck, and put it back with a narrow strip of sheet steel or brass placed alongside of it, the thickness of which will equal the dimension *b*, Fig. 20. When the tool has been tightened in the chuck, light cuts can be taken until the desired amount of material has been removed. When the tool has been turned eccentric, as shown at *C*, a small groove is milled in it as shown at *D*, and the tool backed off for clearance. It is then hardened and drawn very carefully in oil. If the amount of eccentricity required on the tool is such that the tool could not be held firmly in a chuck with a piece of sheet steel inserted alongside of it, a bushing should be made with an eccentric hole, the eccentricity of the hole in the bushing being equal to the eccentricity required on the tool.

Chamfering and recessing tools should be made slightly smaller than the diameter of the drilled hole and the body should never be

longer than is necessary to clear the work, allow the chips to pass out, and the oil to penetrate to the cutting edge. For general conditions the following proportions for chamfering and recessing tools will be found satisfactory:

Proportions for Chamfering Tools (for Notation see Fig. 17)

A = diameter of hole before reaming, or diameter of drill,
B = diameter of chamfering tool = A — 0.025 to 0.030 inch,
C = diameter of chamfered hole,
D = length of work, or distance that tool projects in from the face of the work,
E = length of body of tool = 1.25 D,
F = diameter of body of tool (when included angle = 90 degrees) = B — ($2H$ + 0.025 to 0.030 inch).
G = width of blade = 0.25 B = $2H$,
I = diameter of shank, as follows:

When A = from ⅛ to ¼ inch, I = ¼ inch.
A = from ¼ to ½ inch, I = ½ inch.
A = from ½ to ⅞ inch, I = 1 inch.

K = total length of tool, as follows:

When I = ¼ inch, K = E + ⅞ inch.
I = ½ inch, K = E + 1¼ inch.
I = 1 inch, K = E + 1½ inch.

Proportions for Recessing Tools (for Notation see Fig. 18)

A = diameter of hole before reaming, or diameter of drill,
B = diameter of recessing tool = A — 0.025 to 0.030 inch,
C = diameter of recessed hole,
D = distance from face of work to extreme depth of recessed hole,
E = length of body of tool = 1.25 D,
F = diameter of body of tool = B — (C — B + 0.020),
G = width of blade = 0.2 B,
H = diameter of shank, as follows:

When A is from ⅛ to ¼ inch, H = ¼ inch.
A is from ¼ to ½ inch, H = ½ inch.
A is from ½ to ⅞ inch, H = 1 inch.

I = total length of tool, as follows:

When H = ¼ inch, I = E + ⅞ inch.
H = ½ inch, I = E + 1¼ inch.
H = 1 inch, I = E + 1½ inch.

Proportions for Tools used in Recessing Holes of Small Diameter (for Notation see Fig. 19)

A = diameter of hole before recessing, or diameter of drill,
B = depth of recess,
C = diameter of cutting portion of recessing tool = A — from 0.010 to 0.020 inch,
D = diameter of eccentric body of tool = C — (B + from 0.010 to 0.020 inch),

E = distance from face of work to extreme depth of recessed hole,
F = length of body of tool = 1.20 E,
G = width of blade = 0.20 C,
H = diameter of shank of tool, which is the same as previously given for the tools shown in Figs. 18 and 19.
I = total length of tool, as follows:

When H is ¼ inch, $I = F +$ ⅞ inch.
H is ½ inch, $I = F + 1¼$ inch.
H is 1 inch, $I = F + 1½$ inch.

It will be noted that the lengths of the bodies E and F on chamfering and recessing tools, respectively, will be governed to a considerable extent by the character of the holder used, and the relative positions of the cross-slide tools during the recessing operation, and also

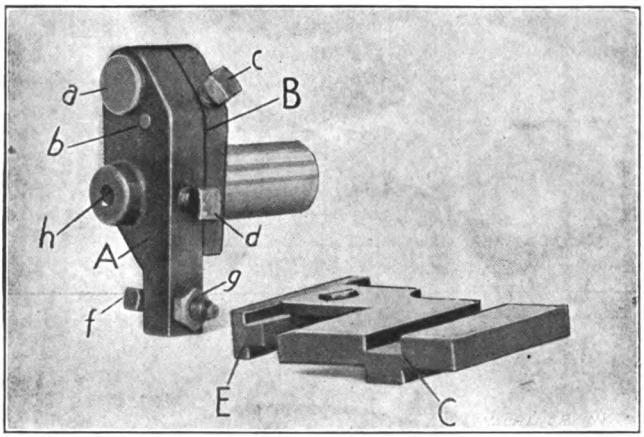


Fig. 21. B. & S. Swing Tool-holder and Rising Block for Operating it

by the depth of recessed hole required. Usually the proportions given will be found satisfactory for general work.

Recessing Tool Holders

In Fig. 21 is shown a recessing tool holder which is commonly called a swing tool. The swinging member A of this holder is held to the body B by a stud and screw a. The pin b held in the swinging member is kept tight up against the end of the set-screw c by means of a small coiled spring, not shown, which is held in the member B. The set-screw c is also used for bringing the tool concentric with the hole in in the work. The set-screw d holds the recessing tool in the swinging holder. To operate this tool, the ordinary rising block which is used under the circular tool holder is removed, as already mentioned, and the block shown to the right in the illustration is substituted in its place. This block is intended only for straight work, the cam E being adjusted longitudinally in a slot in plate C.

The rising block shown in Fig. 22 is adjustable for taper work.

Plate *C* has a longitudinal groove *c* cut in it, in which the adjusting arm *D* can be adjusted in or out, as desired. When the desired position is obtained, it is clamped by means of the screws *d*. On this adjustable plate *D* is fastened a swinging plate which rotates on the small pin *e* and is adjusted by the set-screw *f*. When this plate is set in the desired position it is locked by means of the screw *g*. This rising block can be used for a variety of work, as the setting and shape of the plate *E* will determine the shape produced on the work.

When it is essential to have a hole in the work concentric with the external circumference of the work, a block as shown in Fig. 22 can be used in conjunction with the recessing or swinging tool holder shown in Fig. 21, the operation of truing the hole being similar to

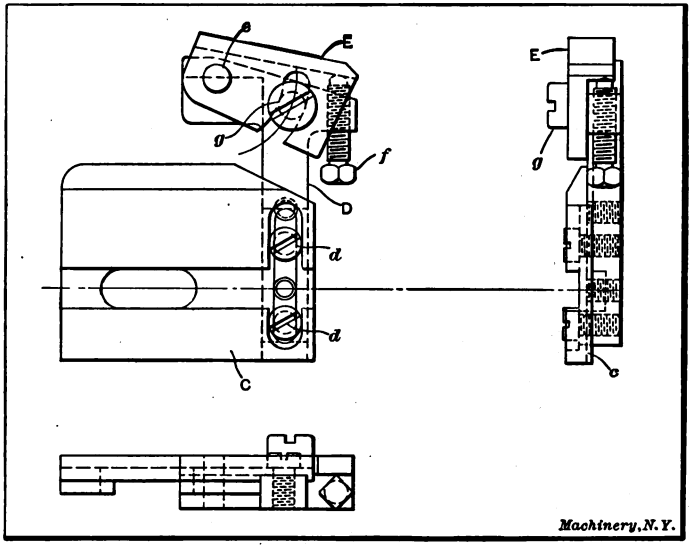


Fig. 22. Standard Rising Block used for Operating Swing Tools

boring a hole in an ordinary lathe. For this class of work, of course, it is usually necessary to take only one cut, so that complicated cams are avoided, but in special cases the work in hand will decide whether it would be advisable to take one or more cuts.

Returning to the swinging tool holder shown in Fig. 21, the set-screw *f* is used for bringing the recessing tool concentric with the hole in the work. A small clamping nut *g* is provided for locking it, when in the desired position. The sizes of the hole *h* in the holders for the various machines do not fit the sizes of shanks for recessing tools recommended above, but are smaller, as follows:

For the No. 00 machine, $h = 3/16$ inch,
No. 0 machine, $h = 1/4$ inch,
No. 2 machine, $h = 1/2$ inch.

For large recessing tools the shank sizes required to fit these holders are rather too small.

In Fig. 23 is shown another design of recessing tool holder which will sometimes be found very convenient. In the tool-holder shown the swinging member *A* is held to the body of the tool-holder *B* by means of the screw *C*. The body of this screw, which passes into the holder *B*, is turned eccentric to that part of the screw which works in the swinging member *A*. A detail view of this screw, used in a holder for a No. 00 machine, is shown to the right in the illustration. It can be seen that a slight adjustment of this screw will locate the recessing tool concentric with the hole in the work. This is found to be a very practicable addition in some cases, especially when the hole in the work is extremely small, not allowing the difference between the external diameter of the recessing tool and that of the hole to be very great. This screw also provides for any inaccuracy in the making of the holder, as it is usually found a difficult proposition to get these tool-holders to line up exactly.

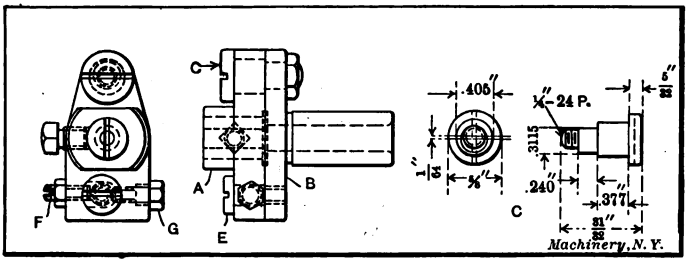


Fig. 23. Another Type of Swing or Recessing Tool Holder

The construction of this holder is somewhat different to that shown in Fig. 21, especially in the method of holding *A* to the member *B*. A shoulder-screw *E* is tapped into part *B* and is made a loose fit in the swinging part *A*, the latter having an elongated hole to allow the holder to swing. The head of the screw *E* allows the swinging part of the holder to slide easily underneath it. This holder has an adjustable stop *F*, so that once the holder is set, it will always come back into the exact position. The set-screw or stop *F* which bears against the body of the screw *E* is locked by means of a nut. *G* is the screw against which the operating cam attached to the rising block bears. This screw has a shoulder against which a small coiled spring acts, thus keeping the screw *F* held in the swinging member *A* up against the screw *E*. Split bushings are used for holding the recessing tools in this holder. This tool can be made very accurately and is used for fine and delicate work.

Performing Facing Operations with Swing Tools

Swing tools are not only used for recessing and chamfering operations, but can also be used for straight, taper and irregular turning operations, and when necessary may be used for facing. It is sometimes found necessary to cup out a piece of work, leaving a very thin wall. Now, if the ordinary facing tool were used in the turret, the

cutting pressure would force this thin wall back, and as soon as relieved of the pressure, it would spring back again to its normal position, or nearly so, thus making it difficult to produce a perfectly square face in the work. For this class of work a swing tool as shown in Fig. 24 is found advisable. When in operation, the facing tool *C* shown in the holder is brought up until the cutting edge is in line with the face of the work. When it is in this position it is fed a slight amount into the work, equal to the depth of the cut to be taken. Then the cross-slide advances, forcing the tool forward, thus turning the face in a manner similar to that of an ordinary facing operation in the lathe. If one cut is not sufficient to true up the face, of course a second cut can be easily taken. This method of turning will be found satisfactory when all others fail. This swing tool is constructed some-

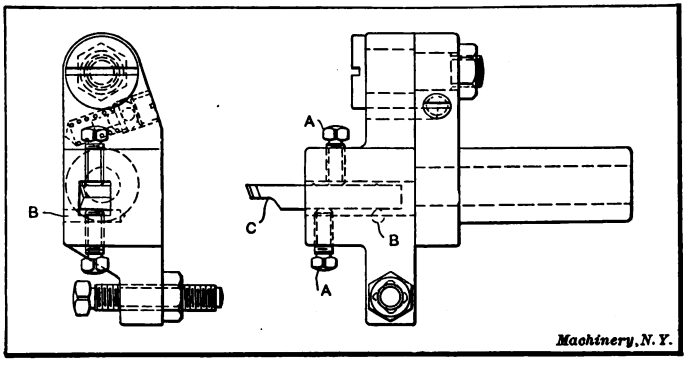


Fig. 24. Swing Tool used for Facing Operations

what similarly to those previously described, with a slight modification to suit the requirements. The turning tool *C* is made from a square section of either carbon or high-speed steel and is adjusted by means of the two set-screws *A*. The turning tool rests on the small pin *B* which acts as a fulcrum. By means of this pin and the two set-screws the tool can be set to the correct height.

When making a cup-shaped piece of work similar to that shown in Fig. 25, usually the best procedure to follow is to first drill, rough counterbore and form all at the same time. A rough counterbore can be used similar to that shown at *B*, Fig. 14. Following the counterboring operation, a swing tool similar to that shown in Fig. 24 is used to square up the inside face which has become slightly concave, due to the fact that the heat generated between the side of the form tool and the work causes the work to spring away from the tool.

If it is necessary to have the back face of the piece square as well as the inside face, a revolving support can be used in the turret, following the rough counterboring operation or the first facing operation, as the case may be; preferably it should follow the facing operation. This support is used in conjunction with a shaving tool carried on either cross-slide, as may be necessary, and is brought up against the inside face of the work. The shaving tool is then fed across the back

face of the work, taking a light shaving cut. If necessary it can also take a light cut off the shank, if it is desired to get the diameter closer than within limits of 0.0015 inch. Care should be taken to have the spindle adjusted so that there is no end play, and to have the dwell on the cam uniform, because if the lobe for the revolving support is not uniform but has slight rises on it, it will produce an uneven finish on the back face of the work, thus defeating the object of the shaving operation.

When the wall is very thin, that is when the distance B equals about ten times the dimension A, two facing cuts should be taken. It is preferable, when performing facing operations of this character, to operate the swing tool from the front cross-slide and start the cut from the center of the work out to the full diameter. Operating the swing tool from the front cross-slide permits the tool to be turned upside down (when the spindle is running forward), thus allowing the chips to be removed easily. However, when high periphery velocities are used on steel, it is generally practicable to have the swing tool operated from the rear cross-slide, or else run the spindle backward, so that a good supply of oil can reach the cutting edge of the tool.

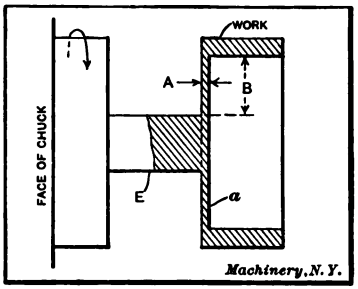


Fig. 25. Diagram giving Notation used in the Derivation of Feeds for Facing Operations

Feeds for Facing Operations

The feeds and depths of chip for facing operations are given in Table VI. The values of C in the first column equal B divided by A (see Fig. 25). For example, assume that $B = 0.25$ inch. Then when $A = 0.025$ inch, $C = \frac{0.250}{0.0250} = 10$, or, in other words, $B = 10$ times A.

It will be noted that the feeds given are approximately the same for brass rod and machine steel; this has been found satisfactory. When the distance B is greater than 12 times A, the form tool, or other means of supporting the thin wall against the pressure of the cut should be provided. Where the form tool is used for this purpose it should be made perfectly straight, that is, without side clearance, and it should be ground and lapped. In this operation the form tool is dropped back from the shank E of the work to a distance about 0.010 inch and allowed to dwell in this position until the facing operation is completed. A copious supply of good lard oil should be supplied to the tools. The feeds under these conditions can sometimes exceed those given in Table VI.

Rise on Cross-slide Cam for Recessing and Chamfering

When using the recessing holders previously described it is obvious that the rise on the cam will be greater than the distance which the

tool is fed into the work. To illustrate the method of finding the rise on the cam, refer to Fig. 26, where

A = distanee from center of fulcrum to center of the recessing tool,
B = distance from center of fulcrum to point of application of cam or center of screw f. (see Fig. 21),
C = diameter of recessing tool,
D = diameter of drilled hole in the work,
E = diameter of recessed hole,

TABLE VI. FEEDS FOR FACING TOOLS MADE FROM HIGH-SPEED AND CARBON STEEL

Value of C	Brass Rod, Feed per Revolution	Machine Steel, Feed per Revolution	Tool Steel, Feed per Revolution
0.002-inch Chip			
12.0	0.0008	0.0007	0.0005
11.0	0.0010	0.0009	0.0007
10.0	0.0020	0.0015	0.0010
9.0	0.0030	0.0025	0.0015
8.0	0.0040	0.0030	0.0020
0.005-inch Chip			
7.0	0.0040	0.0030	0.0020
6.5	0.0050	0.0038	0.0022
6.0	0.0055	0.0040	0.0025
5.5	0.0060	0.0045	0.0028
5.0	0.0070	0.0050	0.0030
0.010-inch Chip			
4.5	0.0048	0.0030	0.0030
4.0	0.0050	0.0034	0.0034
3.5	0.0055	0.0037	0.0037
3.0	0.0060	0.0040	0.0040

r = travel of recessing tool $= \dfrac{E-C}{2}$,

R = rise on the cam.

Then $R : r : : B : A$. To illustrate this more clearly we will take a practical example. Let r equal 0.040 inch; B, 2¼ inches; A, 1⅛ inch; then $R = \dfrac{0.040 \times 2\frac{1}{4}}{1\frac{1}{8}} = 0.080$ inch.

Care should be taken to set the recessing tool exactly in the center of the hole, so that it will not strike the side when being forced into or backed out of the work. If care is not taken in this respect, the appearance of the work turned out will not be creditable, and the tool may be broken.

Cam Lever Templets for Laying out Cams

In Fig. 27 are shown the cam lever templets for the Nos. 00, 0, 1 and 2 Brown & Sharpe automatic screw machines. These templets are used for laying out cams when it is necessary to have the starting or finishing points of the lobes on the cross-slide and lead cams in a certain definite relation to each other.

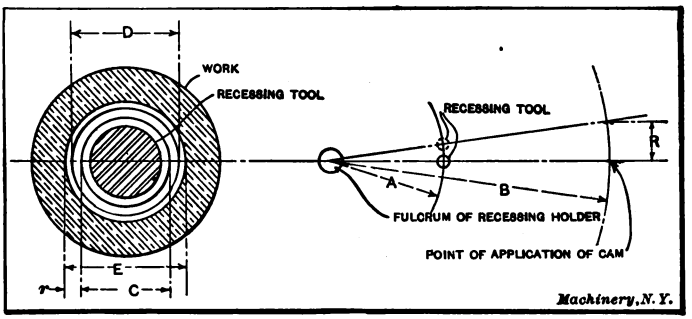


Fig. 26. Diagram for finding Rise on Cross-slide Cam for Recessing and Chamfering Operations

These templets are used as follows: The center *A* is pivoted at the center of the cam drawing by a pin or other pointed instrument which is inserted in the center hole provided in the lever. The main body of the templet *B* can then be rotated in any desired position so that

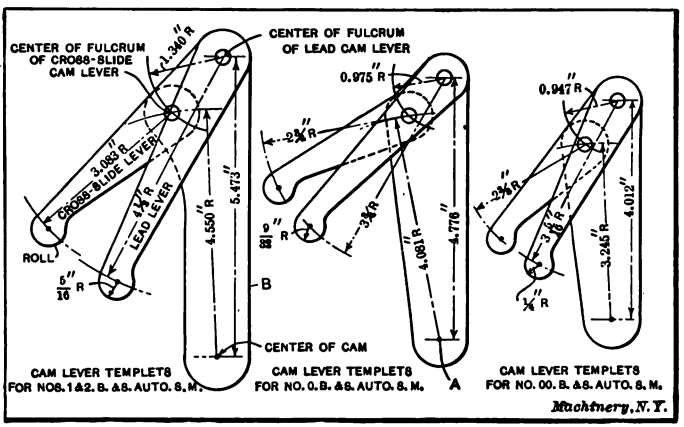


Fig. 27. Nos. 00, 0, 1 and 2, B. & S. Automatic Screw Machine Cam Lever Templets for finding the Starting and Finishing Points of the Lobes for the Cross-slide and Lead Cams

the rolls of the cam levers can be set in their respective relations to each other. In this way the starting or finishing points of the lead and cross-slide cam lobes can very easily be obtained, as will be further explained in the following.

These cam lever templets are made from sheet celluloid, thus making them transparent so that any marks placed on the drawing can

easily be detected, such as the location of the roll, whether on the top of the lobe, on the rise of the lobe, or on the drop of it. The templets are manufactured by the Brown & Sharpe Mfg. Co., Providence, R. I.

Methods of Laying out Cams for Chamfering

In Fig. 28 is shown a method for finding the starting and finishing points on the lobes of the cross-slide and lead cams for chamfering. These points can very easily be obtained by means of the cam lever templets shown in Fig. 27. As was previously explained in regard to these templets the center *A* (see Fig. 27) is pivoted at the center of the cam.

There are two methods used in laying out a set of cams when it is necessary to obtain clearances or definite starting points for the lead and cross-slide lobes. The first one is to obtain a rough estimate of the total number of revolutions required to complete one piece, after which the revolutions are transferred into hundredths of cam circumference, and the location of the lobes laid out on the cam circles. Then the rises and drops are constructed and the amount of clearance obtained by the cam lever templets. This method usually requires considerable experience in this line of work.

Another method, and one which the writer considers superior to that given, is to first find the rise on the cross-slide cam for chamfering (see Fig. 26). Then draw a diagram as shown in Fig. 28. First draw circles *L* and *S*, representing the largest diameter of the lead cam and the largest diameter of the cross-slide cam, respectively. Then draw another circle *H* a distance *R* inside of the circle *S*, as shown, the dimension *R* being the rise on the cross-slide cam. It is obvoius that in chamfering operations the tool should have been moved longitudinally the proper distance into the work before the cross-slide cam starts to operate upon it. Therefore, the lead-cam roll should be on the highest point of the lobe before the cam on the cross-slide, used for feeding in the tool, touches the tool holder. In order to accomplish this result, proceed as follows. Draw a circle *G*, as shown in Fig. 28, which has a radius an amount $R + D + \frac{1}{16}$ smaller than that of circle *S*. The value of *D* is shown in Fig. 17; the 1/16 inch added to *D* allows for clearance. After these circles have been drawn, we can find the starting and finishing points of the lobes.

The cam lever templet is now brought into position, and the lead cam roll placed so that its circumference touches the lobe on the lead cam and its center coincides with the line *A* indicating the completion of the lead-cam rise. Then the cross-slide lever is swung down so that the circumference of the roll touches the circle *G* as shown, and with a sharp pencil a line is scribed around the circumference of the roll, which will determine the quick rise of the cam. The compasses are then set to the desired radius for the quick rise of the cam which is described so that it will cut the circle *H*, representing the start of the rise on the cross-slide cam, and also be tangent to the line which has been previously marked by scribing around the cross-slide lever roll.

Where the quick rise of the cam and the circle *H* meet, will be the starting point of the rise on the cross-slide cam, indicated by the line *B* as shown.

When we have found the starting points, the next thing is to obtain the ending or "finish" points of the lobe. It is obvious that the lead cam should hold the tool in position until the cross-slide cam has dropped back an amount equal to the distance which it has forced the tool into the work. A line *F* is taken at any convenient position for the "finish" of the lead cam, and the cam lever templet is then brought into position so that the roll of the lead lever touches the circle and the center coincides with the line *F* as shown. The cross-slide roll is then swung down until its circumference touches the circle *H* and a line is scribed around the circumference of the roll. Where this line

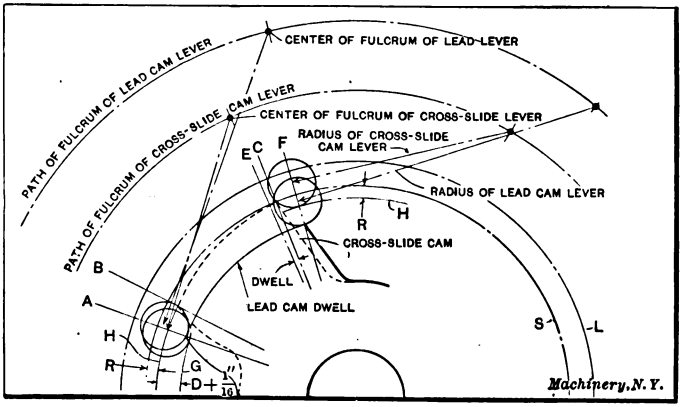


Fig. 28. Diagram for finding the Starting and Finishing Points of the Lobes of the Cross-slide and Lead Cams for Chamfering Operations

intersects the circle representing the largest diameter of the cam, will be the finishing point of the lobe, provided the distance *R* is not greater than the radius of the roll. If distance *R* is greater than this, the line representing the drop should be constructed tangent to the roll circumference, and where the line representing the drop intersects the outside circle will be the finishing point of the lobe, as indicated by line *C*. The space from *E* to *C* represents from one to two revolutions for dwell on the cross-slide cam.

Now it can be clearly seen that the advantage of this method is that the amount of clearance between the starting and finishing points of the lead and cross-slide cams is known in hundredths of the cam circle circumference before the cams themselves are laid out, thus facilitating the operation of laying out the cams.

Methods of Laying out Cams for Recessing

In Fig. 29 a method is shown for finding the starting and finishing points on the lobes of the cross-slide and lead cams for recessing. To determine these points the cam lever templets are again brought into

operation. The starting point, determined by line *A*, and the circle representing the dwell on the lead cam are first laid out. A circle is then drawn, the radius of which is a distance *K* (see Figs. 18 and 19) greater than the circle representing the dwell on the lead cam. Before this is done, of course, a maximum diameter of cam should be decided upon, which will suit the length of the tool-holder used in the turret. A circle passing through the starting point of the rise of the cross-slide cam, as well as a circle representing the dwell on the cross-slide cam should also be drawn, the difference in radii between these two circles being the rise *R*. Now the cam lever templets are placed in position on the drawing, and the lead roll brought down so that it touches the lead cam, its center coinciding with line *A*. A circle *M* is next drawn, having a radius $L + \frac{1}{16}$ inch less than that of the circle

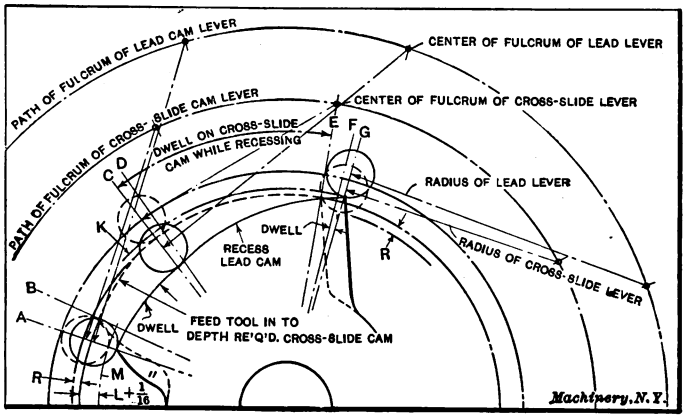

PATH OF FULCRUM OF LEAD CAM LEVER
CENTER OF FULCRUM OF LEAD LEVER
PATH OF FULCRUM OF CROSS-SLIDE CAM LEVER
CENTER OF FULCRUM OF CROSS-SLIDE LEVER
DWELL ON CROSS-SLIDE CAM WHILE RECESSING
RADIUS OF LEAD LEVER
RECESS LEAD CAM
DWELL
RADIUS OF CROSS-SLIDE LEVER
FEED TOOL IN TO DEPTH RE'Q'D. CROSS-SLIDE CAM
DWELL
Machinery, N.Y.

Fig. 29. Diagram for finding the Starting and Finishing Points on the Lobes of the Cross-slide and Lead Cams for Recessing Operations

passing through the starting point of the rise of the cross-slide cam. (See Fig. 18 for dimension *L*). The cross-slide roll is then swung down until its circumference touches the circle *M*, as shown, and a line is drawn around the circumference of the roll. The quick rise line of the cam is then constructed tangent to the roll, and where this line intersects the circle previously drawn and which determines the beginning of the slow feeding-in rise of the cross-slide cam, is the starting point of the slower rise of the cross-slide cam, as shown at *B*. The line *C*, which represents the finishing point of the rise on the cross-slide cam for feeding the tool in to take the desired chip, is then laid off and the cross-slide roll swung into position. The lead roll is then swung down until it touches the circle representing the dwell on the lead cam. The starting point of the rise on the lead cam, located on line *D*, is slightly in advance of the finishing point on the cross-slide cam.

The finishing points of the lobes are the next things that require attention. Any line, as *G*, is taken at a convenient location, and the

cam lever templets are then brought into operation. The lead roll is first brought into position as shown, and then the cross-slide roll is swung down from the outside diameter of the cam a distance equal to *R*, and the drop laid off as before mentioned in regard to chamfering operations. The finishing point of the cross-slide lobe would then be on the line *E*. The space from *C* to *E* on the cross-slide cam would be for dwell, while the space from *D* to *G* on the lead cam would be the rise. The space from *F* to *G* is for dwell on the lead cam, which represents about one or two revolutions.

Speeds for Chamfering and Recessing Tools

The surface speeds used for reeessing tools can be slightly greater than those used for counterbores on account of the light feeds and

TABLE VII. FEEDS FOR CHAMFERING TOOLS MADE FROM HIGH-SPEED AND CARBON STEELS

Diameter of Chamfering Tool in Inches	Brass Rod, Feed per Revolution	Machine Steel, Feed, per Revolution	Tool Steel, Feed per Revolution
$\frac{1}{8}$	0.0010	0.0008	0.0005
$\frac{3}{16}$	0.0015	0.0010	0.0008
$\frac{1}{4}$	0.0018	0.0015	0.0010
$\frac{5}{16}$	0.0020	0.0020	0.0012
$\frac{3}{8}$	0.0030	0.0022	0.0015
$\frac{7}{16}$	0.0040	0.0025	0.0018
$\frac{1}{2}$	0.0048	0.0030	0.0020
$\frac{9}{16}$	0.0055	0.0035	0.0021
$\frac{5}{8}$	0.0060	0.0038	0.0022
$\frac{11}{16}$	0.0065	0.0040	0.0024
$\frac{3}{4}$	0.0070	0.0045	0.0026
$\frac{13}{16}$	0.0075	0.0048	0.0028
$\frac{7}{8}$	0.0080	0.0050	0.0030

small amount of cutting surface in contact with the work. As a rule, the following surface speeds can be used on the materials specified with satisfactory results:

SPEEDS FOR RECESSING TOOLS MADE FROM CARBON STEEL

Material	Surface Speed in Feet per Minute
Brass (ordinary quality)	170-180
Gun-screw iron	60-70
Norway iron and machine steel	45-55
Drill rod and tool steel	35-40

SPEEDS FOR RECESSING TOOLS MADE FROM HIGH-SPEED STEEL

Material	Surface Speed in Feet per Minute
Brass (ordinary quality)	200-225
Gun-screw iron	90-100
Norway iron or machine steel	75-85
Drill rod and tool steel	50-60

TABLE VIII. FEEDS FOR RECESSING TOOLS MADE FROM HIGH-SPEED AND CARBON STEEL

0.010-inch Chip				1/32-inch Chip			
Diameter of Recessing Tool in Inches	Brass Rod, Feed per Revolution	Machine Steel, Feed per Revolution	Tool Steel, Feed per Revolution	Diameter of Recessing Tool in Inches	Brass Rod, Feed per Revolution	Machine Steel, Feed per Revolution	Tool Steel, Feed per Revolution
1/8	0.0020	0.0012	0.0010	3/8	0.0040	0.0025	0.0015
9/64	0.0030	0.0018	0.0015	7/16	0.0045	0.0030	0.0020
5/32	0.0040	0.0025	0.0020	1/2	0.0055	0.0040	0.0025
11/64	0.0080	0.0040	0.0040	9/16	0.0075	0.0050	0.0030
3/16	0.0120	0.0060	0.0050	5/8	0.0085	0.0060	0.0035
13/64	0.0160	0.0090	0.0060	11/16	0.0100	0.0065	0.0038
7/32	0.0200	0.0100	0.0070	3/4	0.0120	0.0070	0.0040
0.020-inch Chip				1/16-inch Chip			
1/4	0.0025	0.0015	0.0010	1/2	0.0080	0.0020	0.0010
9/32	0.0035	0.0020	0.0015	9/16	0.0040	0.0028	0.0015
5/16	0.0050	0.0030	0.0020	5/8	0.0050	0.0030	0.0020
11/32	0 0080	0.0050	0.0040	11/16	0.0060	0.0035	0.0028
7/16	0.0120	0.0070	0.0050	3/4	0.0075	0.0040	0.0025
15/32	0 0160	0.0090	0.0055	13/16	0.0080	0.0045	0.0028
1/2	0 0190	0.0100	0.0060	7/8	0.0085	0.0050	0.0030

Feeds for Chamfering

In Table VII are given the feeds to be used for chamfering tools when cutting various materials, and when the tools are of the diameters specified. It is obvious that the greater the length of the body of the tool is in proportion to its diameter, the smaller will be the feed. This should be taken into consideration when applying the feeds given. These feeds are for chamfering tools having the proportions given in Figs. 17 to 19, inclusive. When the diameter of the body is smaller in proportion to its length than given in Figs. 17

to 19, it would be advisable in most cases to use a slightly decreased feed. No definite rule, however, can be given for this, as the conditions vary so much. Therefore, the feed to be used will practically be a matter of judgment and can be found in no other way than by experience.

Feeds for Recessing

In Table VIII are given the feeds to be used when a chip from 0.010 to 1/16 inch thick is being removed. The same feeds as given in Table VII are used for feeding the recessing tool into the depth of chip required, while the feeds given in Table VIII are used for feeding the tool longitudinally. The same conditions as previously mentioned in connection with chamfering tools should be taken into consideration here also. For general conditions and for recessing tools made to proportions given in Figs. 17 to 19 the feeds in Table VIII will be found satisfactory. In steel work, especially, it is usually found advisable to decrease the feed as the tool approaches the end of its cut, when a chip varying from 1/32 to 1/16 inch thick is taken. This rule is also followed when a finishing cut is taken with a box-tool up to a shoulder.

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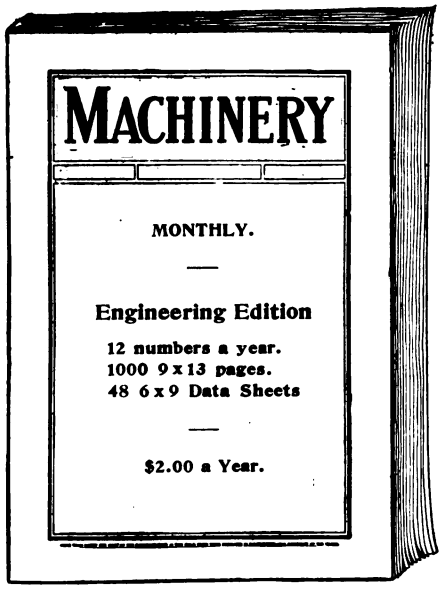

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